261

CONSEIL PERMANENT INTERNATIONAL
POUR L'EXPLORATION DE LA MER
CHARLOTTENLUND SLOT – DANEMARK

MAR 2 1953
LIBRARY
FISH & WILDLIFE SERVICE
PACIFIC OCEANIC FISHERY
INVESTIGATIONS

JOURNAL DU CONSEIL

VOL. XVIII · NO. 3

PUBLIÉ PAR LE BUREAU DU CONSEIL

RÉDIGÉ PAR
J. R. LUMBY

EN COMMISSION CHEZ
ANDR. FRED. HØST & FILS
COPENHAGUE

JANVIER 1953

Notice.

The Journal of the Council appears *three times a year,* and three numbers form a volume. It includes, in addition to general articles, reviews, and bibliography, the special papers previously issued in the series of *Publications de Circonstance.*

The Bureau regret to say that increased printing expenses have made it necessary to raise the annual subscribtion price to **30.00 Kroner** (+ mailing expenses) a volume. Single copies are sold at Kr. 12.00. The subscription price includes, as formerly, if desired, a reprint of the bibliographical matter, printed on one side of the paper.

Orders for copies should be sent to **Messrs. Andr. Fred. Høst & Son, Bredgade, Copenhagen.**

Correspondence, books and papers for review or bibliographical notice, and all contributions to the Journal, should be addressed to the **Editor, Journal du Conseil, Fisheries Laboratory, Lowestoft, England.**

CONSEIL PERMANENT INTERNATIONAL
POUR L'EXPLORATION DE LA MER
CHARLOTTENLUND SLOT – DANEMARK

JOURNAL DU CONSEIL

VOL. XVIII · NO. 3

PUBLIÉ PAR LE BUREAU DU CONSEIL

RÉDIGÉ PAR
J. R. LUMBY

EN COMMISSION CHEZ
ANDR. FRED. HØST & FILS
COPENHAGUE

JANVIER 1953

IMPRIMERIE A/S L. IHRICH . COPENHAGEN

The Precise and Routine Potentiometric Determination of the Chlorinity of Sea Water.

By

J. M. Bather and **J. P. Riley,**
Department of Oceanography, University of Liverpool.

THE Mohr-Knudsen method (1) has long been used for the routine determination of chlorinity, and in the hands of experienced technicians gives results of accuracy adequate for most purposes. It is, however, not sufficiently accurate for the examination of samples where the detection of small chlorinity variations is important as the colour at the end point is rather difficult to see and fades rapidly.

Where results of the highest accuracy are required the Volhardt method (2) has usually been employed, but owing to the difficulty in washing the silver halide precipitate free from silver nitrate it is very slow.

With the object of speeding up the titrations several workers have proposed electrometric methods for the detection of the end point of the titration of sea water with silver nitrate solution, the main differences between them lying in the electrode systems used. West and Robinson (3) used graphite and platinum or tungsten electrodes, but the potential change of such a bimetallic system at the end point is quite small, and furthermore, the use of graphite as an electrode material is objectionable on electrochemical grounds. Anderson and Moberg (4) applied a silver chloride electrode as an indicator electrode, and a platinum-potassium nitrate reference electrode to the precise determination of chlorinity. More recently Hermann (5) has employed a silver indicator electrode in conjunction with a special type of silver-silver nitrate electrode.

Anderson (6) has described a conductimetric method for the volumetric determination of chlorinity, for which he claimed an accuracy of 0·01 $^0/_0$. His procedure was not, however, suitable for routine work and required rather elaborate apparatus.

The present work describes a rapid and purely volumetric method for the determination of chlorinity, having an accuracy approximately the same as the method of Hermann (loc. cit.), and which can be used by relatively unskilled persons with very little practice.

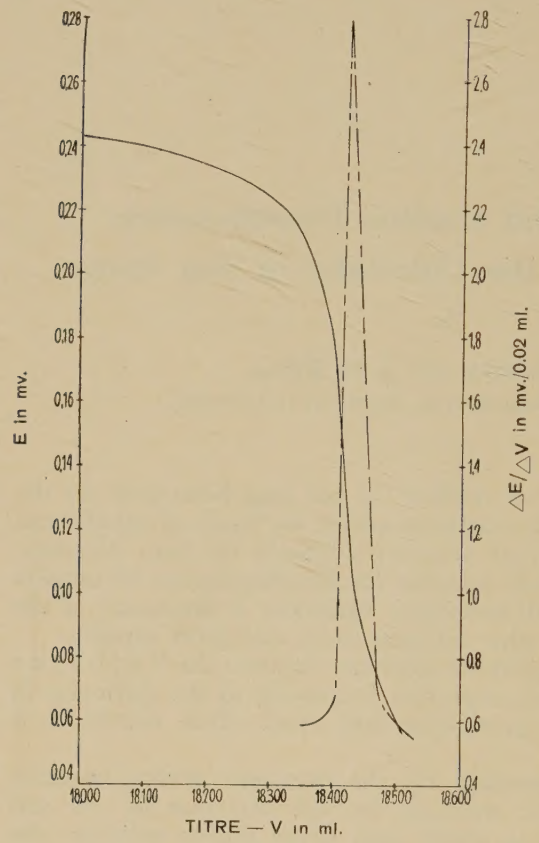


Figure 1.
(I) Continuous Line — Graph of Potential, E, against Titre, V.
(II) Discontinuous Line — Graph of Increment $\triangle E/\triangle V$ against Titre, V.

Experiments were carried out using the electrode system of Hindman *et al.* (3). It was found that consistent results could not be obtained after the electrodes had been used a few times, owing to the changes in the silver chloride electrode[1]). Silver electrodes were also found to be somewhat unreliable.

A considerable number of indicator electrodes made of other materials were tried, but the only ones which gave a sufficiently sharp and reproducible change at the end point were gold and platinum. Platinum was finally chosen since such electrodes are readily constructed and are less easily bent than those of gold. It has been known for some time that platinum electrodes follow the silver-ion concentration during the titration of chloride with silver nitrate (cf. Furman (7)). The exact electrochemical mechanism of the platinum electrode in this reaction is obscure, but almost certainly involves the thin film of platinous oxide

[1]) Further work has shown that silver chloride is converted to bromide by the action of the bromide ion in sea water, and therefore yields a different electrode potential.

which is present on the surface of the metal. A mercury-mercurous sulphate half cell was used in all titrations in order to avoid the contamination of the solution which might have occurred if a calomel electrode had been used.

A number of titrations of sea water with silver nitrate solution were made using these electrodes in conjunction with a Cambridge Instruments pH meter. Curves were obtained from these data relating the electrode potential and volume of silver nitrate added, and showed the potential at the end point to be 0·135 ± 0·002 v at 20° (Figure 1). A "Magic Eye" valve voltmeter set to indicate this potential was used in all subsequent work. This type of instrument has the advantage that it is very sensitive, since a change of 1 mv. is detectable. It is also easier to read than the normal type of valve voltmeter; and could be readily adapted for use on board ship since it contains no sensitive galvanometer.

Chlorinity determinations were carried out on weighed 15 ml. samples contained in tall-form beakers, and stirred by an electric motor. Silver nitrate solution (*ca.* 0·217N, standardized by means of "standard sea-water") was run in from a Knudsen bulb burette until the "magic eye" began to close. The titration was continued with *ca.* 0·00434N silver nitrate until the "magic eye" closed. The end point was detectable to within 0·04 ml. of the dilute silver nitrate solution.

The Knudsen bulb burette used for the strong silver nitrate solution was standardized by weighing out measured volumes of the solution (whose density had been accurately determined). An interval of exactly four minutes was allowed between commencement of the titration and reading the burette. It was observed that if the burette was standardized with water appreciable errors resulted owing to the difference in viscosity and surface tension between water and silver nitrate solution. Care was taken that the room temperature did not change by more than 1° while titrations were being carried out, smaller differences in temperature producing negligible effects.

With the apparatus described 40—45 high accuracy chlorinity determinations may be made per day (including time spent in weighing out the samples). For normal routine purposes it is not necessary to weigh out the samples and as many as 80—90 titrations may be carried out in a day, if the next sample is pipetted out while the titration of the previous one with the strong silver nitrate is proceeding.

The apparatus has been in use in these laboratories for over a year for routine and precision titrations, and even in the hands of students has yielded results showing standard deviations of less than 0·01 %.

Experimental.

Solutions

Strong silver nitrate. *ca.* 0·2173N silver nitrate solution (36·93 g. $AgNO_3$/L.) was made up using a graduated and standardized 10·5 l. bottle.

Dilute silver nitrate (*ca.* 0·004346N). 20 ml. of strong silver nitrate solution diluted to 1 litre.

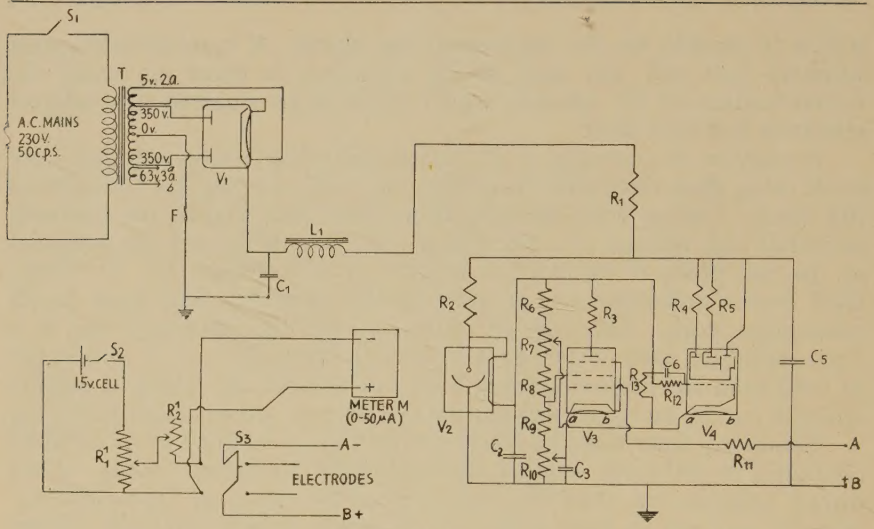


Figure 2. Key:—

Transformer T.
350 — 0 — 350; 100 m.a.
6·3 v. 3 a.
5 v. 3 a.

Choke L.
400 v. 120 m.a.

Valves.
V1 Rectifier U 50.
V2 Stabiliser V.R. 150.
V3 Amplifier 6SJ7.
V4 Magic Eye E.M. 34.

Condensers. (All 450 v. working).
C1 16 μF.
C2, C3 0·1 μF.
C4 0·5 μF.
C5 0·2 μF.

Meter M. 0—200 mv. meter. (British Physical Laboratories 0—50 μA meter, (internal resistance 1500 Ω) was used with an external precision series resistance of 2500 Ω).

Resistances.

R1	10,000 Ω 2 w	R9	4,000 Ω 1 w	Potentiometers.	
R2	3,300 Ω 2 w	R11	10,000 Ω 1 w	R7	5,000 Ω
R3	5,000 Ω 1 w	R12	30,000 Ω 1 w	R10	500 Ω
R4, R5	1 m Ω 1 w	R13	470,000 Ω 1 w	R_1^1	5,000 Ω
R6	10,000 Ω 1 w	R14	1 m Ω 1 w	R_2^1	350 Ω
R8	10,000 Ω 1 w				

Apparatus.

Magic Eye titrometer.

The electronic indicator employed was a more sensitive version of the instrument described by Smith and Sullivan (8). The circuit is shown in Figure 2, and consists of two main parts; a magic eye valve voltmeter and a potentiometer for setting the magic eye to the E.M.F. prevailing at the end point of the titration.

The magic eye unit operated from a 230 v. A.C. mains supply and contained a rectifier valve V_1 (Osram U50), a neon stabilizer V_2 (Brimar VR 150), an amplifier valve V_3 (Brimar 6SJ7), and a magic eye tube V_4 (Mullard E.M.34).

The full wave rectifier, stabilized by means of a neon stabilizer in addition to the normal smoothing circuit produced 150 v. H.T. The

potential from the electrodes of the titration cell was fed into the amplifier stage and the output applied to the magic eye tube. A rotary switch S_3 allowed a standard "setting voltage" to be substituted for the electrode potential. This standard voltage was obtained from a potentiometer network connected across a 1·5 v. dry cell. In the network variable resistances R_1^1 and R_2^1 provided coarse and fine control respectively. Using the millivoltmeter M the voltage was accurately adjusted to 0·135 v. prior to its application to the amplifier.

Control of the magic eye tube to ensure closure at the correct potential was achieved by means of variable resistances R_7 and R_{10} which act respectively as coarse and fine adjustments of the shadow area. In practise R_7 was set so that the fine control R_{10} was approximately at its mid-point when the eye was just closed, with a potential of 0·135 v. applied from the standardizing circuit.

The magic eye tube was mounted inside a brass tube close to the burette taps and was connected to the instrument by means of an 8-cored screened cable. The total cost of the magic eye apparatus was £ 15, including millivoltmeter and cabinet.

For operation on board ship the apparatus can be run from 24-volt batteries through a rotary converter. If desired, the meter M could be dispensed with by obtaining the standardizing potential by using suitable precision fixed resistances as a potential divider in conjunction with a constant-voltage cell.

Operation of the Instrument.

The E.M.34 magic eye tube (V_4) has two shadow areas of quite different sensitivity; in the present work the area of greater sensitivity was used. The characteristics of the tube are such that the maximum sensitivity to potential change is found when the edges of this shadow area are parallel.

The millivoltmeter M was set to 0·135 v. by means of the potentiometers R_1^1 and R_2^1, this potential was then applied by means of the selector switch S_3 to the magic eye circuit. The resistance R_{10} was adjusted until the shadow edges of the magic eye tube were parallel. The switch S_3 was then turned to connect the electrodes to the instrument which was then ready for use.

Electrodes.

Platinum indicator electrode.

9 cm. of 1 mm.-diameter bright platinum wire was hard soldered to a length of 1·5 mm.-diameter copper wire and sealed into a glass tube (internal diameter *ca.* 7 mm.) so that the platinum wire protruded about 7·5 cm. The seal was coated with hard black wax. The electrode was mounted so that even at the end of the titration the seal was about 2·5 cm. above the level of the liquid. After about 100—200 titrations the electrode was apt to become somewhat sluggish and was rejuvenated by immersion first in concentrated ammonium hydroxide solution, and after washing, treated with concentrated nitric acid and finally washed

free from acid. It was then made the cathode against a thin platinum wire anode in *ca.* 3 % solution of sodium borate and electrolysed for two or three minutes, using a 6 volt dry cell as a source of E. M. F. Electrode failure, which occurs very rarely, has been traced to penetration of the titration liquid into the platinum-glass seal: it is therefore most important that the seal be well waxed and not allowed to come into contact with the solution. If the electrode does fail it should be resealed into the glass.

Mercury-mercurous sulphate reference electrode.

The reference electrode, Figure 3, consisted of two concentric tubes. The outer, which contained a saturated solution of potassium and mercurous sulphates, had at the bottom an asbestos wick as used by Zobell and Rittenberg (9). The inner tube contained mercury in contact with a paste of mercurous sulphate which was held in position by an asbestos plug. Contact was made with the mercury by means of a platinum wire sealed in the glass. When not in use, both electrodes were kept immersed in distilled water.

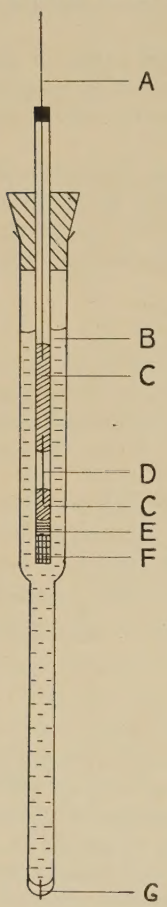


Figure 3. Key:— A, Copper wire; B, Saturated solution of mercurous and potassium sulphates; C, Mercury; D, Platinum wire; E, Mercurous sulphate paste; F, Asbestos plug; G, Asbestos wick.

Burettes.

A Knudsen bulb burette which had been calibrated with the strong silver nitrate solution was used for this reagent. The burette was read 4 minutes after the commencement of the titration.

An ordinary 50 ml. burette was employed for the dilute silver nitrate solution. All volumetric apparatus was cleaned with a mixture of equal parts of concentrated nitric and sulphuric acids.

The total titre was obtained by adding to the reading of the Knudsen burette $^1/_{100}$ of the reading of the dilute silver nitrate burette (since the former is calibrated in units of two cubic centimetres).

Stirring.

The solution was stirred by means of a glass propeller with blades *ca.* 8 mm. long, driven by means of a flexible drive from a well earthed electric motor and controlled by a rheostat.

Procedure.

The samples were pipetted out by means of a 15 ml. Knudsen pipette into weighed tall-form beakers (4·7 cm. in diameter × 9 cm. high) which were immediately reweighed. For normal routine work where lower accuracy sufficed the samples were simply pipetted out, allowing a drainage time of 15 seconds for the pipette.

About 20 ml. of distilled water were added to each sample. The beaker, surrounded by a cylinder af black paper, was placed under the titration apparatus. The magic eye tube was set to an end point potential of 0·135 v. The stirrer was started and the addition of strong silver nitrate solution commenced. The approach of the end point was indicated by a fluttering of the shadow edges of the magic eye tube; the rate of stirring was increased to *ca.* 2500 r. p. m. and the addition of strong silver nitrate continued dropwise until the "eye" began to close. The addition of the strong silver nitrate solution was then discontinued and the tip of the burette rinsed down with distilled water. The setting of the magic eye tube was checked and the titration continued with dilute silver nitrate solution until the shadow edges of the "eye" were parallel. The K n u d s e n burette was read exactly 4 minutes after the beginning of the titration.

Before analysis of the next sample the electrodes and stirrer were rinsed well with distilled water.

Two titrations of standard sea water were run for every ten samples.

Calculation.

Let W_s be the weight of standard sea water
T_s be the total titre of standard sea water
Cl_s be the chlorinity of standard sea water
W be the weight of the unknown sample
T be the total titre of the unknown sample
Cl be the chlorinity of the unknown sample

$$\text{Silver nitrate factor } F = \frac{Cl_s \cdot W_s}{T_s} \quad \text{and} \quad Cl = \frac{F \cdot T}{W} \text{ ‰}$$

Examination of the accuracy of the method.

Five weighed samples of standard sea water(*ca.* 80 ml. Cl 19·371 ‰) were diluted by addition of known weights of distilled water, care

Table I.

Set	F	Temperatures of strong $AgNO_3$	Room
1	15·4140 15·4132	18·9°	21·3°
2	15·4129 15·4140	18·9°	20·9°
3	15·4114 15·4131	19·0°	21·3°
4	15·4136 15·4132	19·1°	21·2°
5	15·4142 15·4144	19·3°	21·5°
mean	15·4134		

standard deviation 0·0056 ‰.

being taken to avoid loss by evaporation. Five titrations were carried out with each of the diluted sea waters. Two undiluted standard sea water samples were titrated before each set of diluted samples, yielding the values shown in Table I for the silver nitrate factor F.

It may thus be seen that though the temperature of the silver nitrate solution changed by 0·4° during the day this did not produce any significant effect on the silver nitrate factor. Each set of titrations on the diluted sea waters was evaluated using the mean of the preceding and following standardization factor, except in the case of the fifth set, which was calculated using the mean of the two preceding factors. The calculated and determined chlorinities of the diluted sea waters are shown in Table II.

Thus there is good agreement between the determined and calculated chlorinities of the samples. The standard deviation of the sets is of the same order as the value of 0·004 ‰ which Hermann (5) obtained in the potentiometric titration of sea water, when the amount of silver nitrate added was determined by weighing.

Table II.

	Set 1	Set 2	Set 3	Set 4	Set 5
determined chlorinity	19·208$_2$	19·014$_6$	18·702$_7$	18·446$_6$	18·234$_0$
	19·208$_9$	19·015$_7$	18·702$_0$	18·442$_6$	18·236$_5$
	19·208$_2$	19·015$_4$	18·702$_3$	18·443$_7$	18·237$_1$
	19·208$_0$	19·015$_1$	18·704$_6$	18·445$_4$	18·236$_4$
	19·208$_1$	19·015$_5$	18·700$_2$	18·443$_8$	18·236$_8$
mean	19·208$_3$	19·015$_3$	18·702$_4$	18·444$_3$	18·236$_1$
standard deviation	0·0022 ‰	0·0024 ‰	0·0086 ‰	0·0087 ‰	0·0072 ‰
calculated chlorinity	19·208$_2$	19·016$_2$	18·703$_1$	18·444$_1$	18·236$_1$

Comparison with the Mohr-Knudsen method.

A comparison of the potentiometric method with the Mohr-Knudsen method was made by carrying out 15 replicate analyses on weighed samples of the same sea water, titrating to the potentiometric end point, adding potassium chromate solution, and continuing the titration until a persistent red colour of silver chromate was obtained. The standard deviations of the potentiometric and Mohr's methods were 0·0051 ‰ and 0·011 ‰ respectively.[1]) As a further test a large number of different weighed samples were titrated in the same manner (Table III), the constancy of the ratio — Mohr's method titre/potentiometric titre — reflects the agreement between the two procedures.

[1]) King (10) considers that results reliable to Cl 0·01 ‰ can be obtained by means of the Mohr method. He did not, however, use mechanical stirring to break up the curds of silver chloride, which we have found much increases the accuracy.

Table III.

Origin of Samples	Number of determinations	Mean value of Mohr titre / potentiometric titre	Standard deviation %
Standard sea water	6	1·00285	0·0120
Standard sea water	20	1·00275	0·0155
Liverpool Bar	9	1·00323	0·0097
Liverpool Bar	9	1·00297	0·0160
Kish	12	1·00301	0·0091
Larne—Stranraer halfway	12	1·00307	0·0172
Bardsey	12	1·00290	0·0143
Holyhead—Kish halfway	12	1·00303	0·0159
Holyhead	11	1·00290	0·0174
Fishguard	8	1·00301	0·0077
		weighted mean 1·00295	
		standard deviation 0·0146 %	

Effect of variation of pH of sea water on potentiometric titration.

Since the mechanism of the platinum electrode in the titration of chloride is probably dependent on the formation of a platinous oxide film, and as it is well known that oxide electrodes are somewhat sensitive to changes in pH, the effect of variation of the acidity of sea water on the accuracy has been studied. Weighed 15 ml. samples of a sea water (Cl = 18·875 ‰) were acidified with varying amounts of $N/_{1000}$ nitric acid and titrated potentiometrically with silver nitrate solution, with the results shown in Table IV.

Table IV.

ml. of 0.001N nitric acid added	pH[3])	titre	ml. of 0.001N nitric acid added	pH[3])	titre
0	7·76	18·810	25	6·49	18·809
1	7·72	18·810	50[1]	3·11	18·804
5	7·44	18·811	100[2]	2·65	18·783
10	7·09	18·811			

[1]) 5 ml. of 0·01 N nitric acid.
[2]) 10 ml. of 0·01 N nitric acid.
[3]) Determined with a glass electrode.

The method should not therefore be applied to samples having a pH much less than 6·5. Since normal sea waters have a pH of 7·6—8·4, and even in stagnant basins where hydrogen sulphide is present, the pH rarely falls much below 7·0 (cf. Ström (11)) this does not in any way limit the application of the method.

Acknowledgment.

The authors wish to thank Dr. C. Barker for his advice during the construction of the "magic eye" titrometer.

Summary.

A rapid and precise volumetric method is described for the determination of the chlorinity of sea waters. A system consisting of a platinum indicator electrode and mercury-mercurous sulphate half cell has been used in conjunction with a highly sensitive "magic eye" valve voltmeter for the detection of the end point. A standard deviation in the titration of ca. 0·005 $^0/_0$ was obtained (corresponding to 0·001 $^0/_{00}$ Cl). The effect of variation of pH on the titration has been studied.

References.

1. Thomsen, H. "Instructions pratiques sur la détermination de la salinité de l'eau de mer par la méthode de titrage Mohr-Knudsen." Bull. Inst. Océanogr. Monaco, No. 930, 1948.
2. Jacobsen, J. P., & Knudsen, M. "Urnormal 1937 or primary standard sea water 1937." Publ. Sci. Assoc. Ocean. Phys., **7**, 1940.
3. West, L. E., & Robinson, R. J. "Potentiometric analysis of sea water. I. Determination of chlorinity." Journ. Mar. Res., **4**, (1), p. 1, 1941.
4. Hindman, J. C., Anderson, L. J., & Moberg, E. G. "A precise determination of chlorinity of sea water using the Ag-AgCl indicator electrode." ibid., **8**, (1), p. 30, 1949.
5. Hermann, F. "High accuracy potentiometric determination of the chlorinity of sea water." Journ. du Cons., **17**, 3, p. 223, 1951.
6. Anderson, L. J. "Conductiometric titration of chloride in sea water and marine sediments." Ind. Eng. Chem. (Anal.), **20**, (7), 619, 1948.
7. Furman, N. H. "Potentiometric titrations." Analytical Chem., **23**, (1), 21, 1951.
8. Smith, G. F., & Sullivan, V. R. "The electron-beam sectrometer. A line operated vacuum-tube titrometer for potentiometric titrations with cathode ray tube replacement of the microammeter." J. Soc. Chem. Ind. (Trans.), **56**, (3), p. 105, 1937.
9. ZoBell, C. E., & Rittenberg, S. L. "An asbestos KCl bridge and a simple calomel electrode." Science, **86**, p. 502, 1937.
10. King, J. "Some notes on the determination of the Chlorinity of Sea-water by comparison with the international standard." Journ. du Cons., **16**, 2, p. 167, 1950.
11. Strøm, K. M. "Land-locked waters. Hydrography and bottom deposits in badly ventilated Norwegian fjords with remarks upon sedimentation under anaerobic conditions." Skr. Norsk. Vid.-Akad. Oslo, Math.-Naturv. Kl., No. 7, 85 pp., 1936.

On Conditions for the Vernal Blooming of Phytoplankton.

By

H. U. Sverdrup,

Norsk Polarinstitutt, Oslo.

IN order that the vernal blooming of phytoplankton shall begin it is necessary that in the surface layer the production of organic matter by photosynthesis exceeds the destruction by respiration. The destruction of organic matter by respiration goes on continuously wherever there are plants or animals, but photosynthesis can take place only in the presence of light, carbon dioxide, and nutrient salt such as nitrates, phosphates, and other minor constituents. Gran and Braarud (1935) have pointed out that production cannot exceed destruction if there exists a deep mixed top layer. Their reasoning is that within a well mixed layer the plankton organisms are about evenly distributed, but a net production takes place only above the compensation depth, whereas below the compensation depth there is a net loss of organic matter. The total population cannot increase if this loss exceeds the net production.

The reasoning is illustrated in Figure 1, where the curves dp and dr show the increase of organic matter by photosynthesis and the decrease by respiration, respectively, as functions of depth. Both increase and decrease apply to unit volume and unit time. The production is supposed to decrease logarithmically with depth, corresponding to the logarithmic decrease of light intensity, but the destruction is supposed to be independent of depth in agreement with the assumption that the organisms are evenly distributed in the mixed layer. At the compensation depth, D_c (Fig. 1), gain and loss balance each other, $dp = dr$. The condition for an increase of the total population is that the total production P must exceed the total destruction by respiration, R, or in our representation, that on an average for 24 hours the area *acd* must be greater than the area *abcd*. This implies that there must exist a *critical depth* such that blooming can occur only if the depth of the mixed layer is *less* than the critical value.

Gran and Braarud concluded that the critical depth was 5 to 10 times the compensation depth. Riley (1942) has carried some of these ideas further and has shown that on Georges Bank there existed in the spring of 1941 a relation between plankton and stability. We will attempt a more precise description of the conditions that are shown in Figure 1 and, on certain assumptions, we will derive an analytical expression for the critical depth.

Our assumptions are:—

1. There exists a thoroughly mixed top layer of thickness D.
2. Within the top layer the turbulence is strong enough to distribute the plankton organisms evenly through the layer.
3. Within the top layer the production is not limited by lack of plant-nutrition salts.

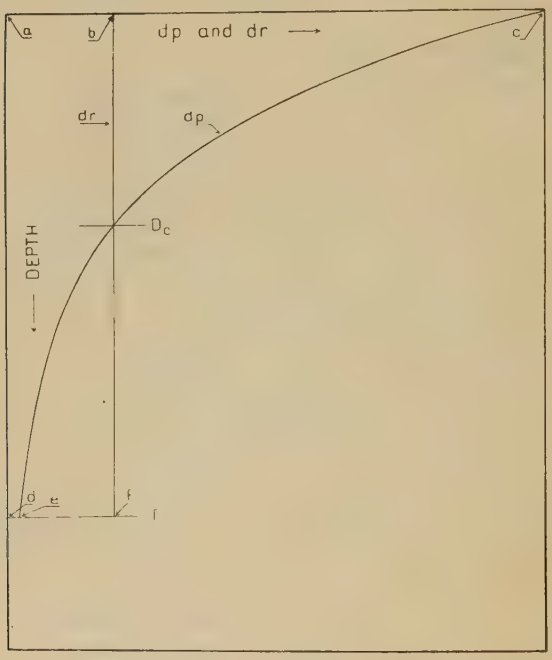


Figure 1. Schematic representation of the variation with depth of the increase of organic matter by photosynthesis, *dp*, and the decrease by respiration, *dr*. Increase and decrease apply to unit volume and unit time.

4. Within the top layer the extinction coefficient, k, of radiation energy is constant. This assumption is not quite correct even if the transparency of the water is independent of depth because, owing to selective absorption, the spectrum of the radiation changes with depth. The wave-lengths for which the extinction coefficient is smallest penetrate to the greatest depths, for which reason the extinction coefficient for total energy decreases with depth (Sverdrup *et al.*, 1942, p. 107; Jerlov, 1951). However, below a depth of a few metres the decrease is so small that the introduction of a constant value of the coefficient does not lead to a serious error, provided that the transparency of the water does not change greatly with depth.

5. When dealing with photosynthesis it is not necessary to consider the energy at wave-lengths shorter than 4200 or longer than 5600 Å. This assumption is justified because for the shorter and the longer wave-lengths the extinction coefficients are so large that the energy associated with these wave-lengths is absorbed in the upper one metre or less. The energy of the spectrum in the wave-length range 4200 to 5600 Å represents about 20 per cent. of the total energy of the incoming radiation, but of the latter a fraction, a, is reflected from the surface.

6. The production of organic matter by photosynthesis is proportional to the energy of the radiation at the level under consideration. According to Jenkins (1937) this assumption is correct if the energy flux is less than 1·8 g. cal. cm.$^{-2}$ hour^{-1}. In spring this condition may be expected to be fulfilled below a depth of a few metres.

7. The energy, I_c, at the compensation depth is known. The compensation depth is defined as the depth at which the energy intensity is such that the production by photosynthesis balances destruction by respiration. This energy level may depend upon the temperature because photosynthesis and respiration may not stand in the same relation to temperature, and it must depend upon the composition of the plankton. It must, for instance, lie higher for a mixed population of phyto- and zooplankton than for a pure phytoplankton population. For the latter it may depend on the species of which the population is composed. By experiments in the English Channel with the diatom *Coscinodiscus excentricus* Jenkins (1937) found the energy at the compensation depth equal to 0·13 g. cal. cm.$^{-2}$ hour^{-1}. Pettersson *et al.* (1934) found a value of 400 luxes in Gullmar Fjord, Sweden, working with a mixed population. Using the same conversion factor as Jenkins this light intensity corresponds to an energy of 0·15 g. cal. cm.$^{-2}$ hour^{-1}.

On the basis of these assumptions we can derive an expression for the critical depth. It will be shown that the critical value depends upon the amount of incoming radiation, the transparency of the water as expressed by the extinction coefficient for total energy, and the energy level at the compensation depth.

Let the total incoming energy from the sun and the sky, expressed in g. cal. cm.$^{-2}$ hour^{-1}, be I_0. Of this amount a fraction, a, is lost by reflection from the sea surface. The energy that passes through the sea surface, I_w, is then $I_w = (1-a)\, I_0$. With a clear sky the fraction a depends upon the altitude of the sun as follows:—

Altitude of sun (°)	5	10	20	30	40	50 to 90
Fraction reflected	·40	·25	·12	·06	·04	·03

With a completely overcast sky the fraction is assumed to have the constant value $a = ·08$.

Of the amount of energy that passes the sea surface only 20 per cent. need be considered when dealing with photosynthesis because the major part is absorbed in the upper one metre (assumption 5). The "effective" energy that passes the sea surface is, therefore, $I_e = 0·2\, I_w$. With a

constant coefficient of extinction, k, the energy that reaches a depth z is then, taking the z-axis position upwards:—

$$I_z = I_e e^{kz} = 0.2\ (1-a)\ I_0 e^{kz} \tag{1}$$

The production at the depth z is supposed to be proportional to the available energy. The production in the time interval dt is then $dp = m\, I_z\, dt$, whereas the destruction in the same time interval is simply $dr = n\, dt$. Here m and n are factors which are independent of z, but depend upon the character of the population and the temperature of the water. By definition $dp = dr$ at the compensation depth where $I_z = I_c$. Therefore, $n/m = I_c$.

In the time, T, the total production by photosynthesis between the surface and the depth $z = -D$ is:—

$$P = m \int_0^T \int_{-D}^0 I_e e^{kz}\, dtdz = \frac{m}{k}\,(1 - e^{-kD}) \int_0^T I_e dt \tag{2}$$

The total destruction is:—

$$R = n \int_0^T \int_{-D}^0 = nTD \tag{3}$$

The condition for an increase of the phytoplankton population is:—

$$P > R \tag{4}$$

Introducing the value for I_e from (2), putting

$$\bar{I}_e = \frac{0.2}{T} \int_0^T (1 - a)\, I_0\, dt \tag{5}$$

and remembering that $n/m = I_c$, we find that the critical depth, D_{cr}, is defined by the equation

$$\frac{D_{cr}}{1 - e^{-kD_{cr}}} = \frac{1}{k}\,\frac{\bar{I}_e}{I_c} \tag{6}$$

So far we have been concerned only with the critical thickness of the mixed top layer, which must not be exceeded if the production in the layer shall be greater than the destruction. It is, however, possible to add a few observations. In the first place it may be pointed out that on the general assumptions made here the rapidity with which a given population may grow depends upon how much the thickness of the top layer deviates from the critical value. If it is only slightly smaller the increase of the total population must be slow, but if it is much smaller, the increase may be very rapid. These conclusions may be greatly modified if grazers are present (Fleming, 1939). In that case the phytoplankton population may remain small in spite of heavy production.

In the second place a phytoplankton population may increase independently of the thickness of the mixed layer if the turbulence is moderate. In this case the plankton may be unevenly distributed at the end of the daylight hours, with greater concentration above the

compensation depth where production has taken place. During the night hours mixing may not be complete and when daylight again makes photosynthesis possible, the concentration of plankton may still be greater near the surface. In these circumstances the production will be greater than according to our assumptions, and the population may increase as long as the conditions prevail. A similar development may take place even with strong turbulence if the phytoplankton displays a positive phototaxis.

Returning to our main topic we may interpret our results in terms of "stabilization". In middle and high latitudes there generally exists a deep mixed layer at the end of the winter, but as the season advances, there develops a shallow mixed layer below which the density increases so rapidly with depth that turbulence is suppressed. By "stabilization" we understand the development of such a layer. This development may be caused by spring heating of the surface layer or by lowering of the salinity of the top layer, related to spring run-off.

Table 1. Thickness of top mixed layer according to observations at Weather Ship "M", 66°N., 2°E.Gr.

Date 1949	Thickness m.	Date 1949	Thickness m.	Date 1949	Thickness m.	Date 1949	Thickness m.
3. March	150	4. April	300	28. April	100—300	16. May	25
7. „	100—150	6. „	50	29. „	100	18. „	100
10. „	100	8. „	100	2. May	100	19. „	100
17. „	100	11. „	50—100	4. „	>150	21. „	0
21. „	150	15. „	200—400	5. „	150	23. „	0
23. „	150	16. „	75—100	6. „	100	25. „	25
26. „	200	22. „	50	11. „	75	27. „	0
30. „	100	25. „	100	12. „	100	28. „	50
2. April	400	27. „	>100	14. „	75	31. „	0

Observations carried out in the spring of 1949 at Weather Ship "M" in the Norwegian Sea (66°N., 2°E. Gr.) make possible a test of our conclusions. The observations comprise measurements of the thickness of the upper mixed layer, counts of the number per litre of phytoplankton organisms at one or more depths near the surface, and counts of the copepods and nauplii as collected by vertical hauls from 100 m. to 50 m. and from 50 m. to the surface. We will deal only with the observations from the months of March, April, and May.

The observations of the thickness of the upper mixed layer were made several times a week. They are based on temperature and salinity observations at fixed depths and on continuous temperature records with the Mosby thermosonde. The latter has a very small scale, for which reason the thickness of the layer can be determined with an accuracy of only ± 25 m. The observed values as communicated by Mr. O. S æ l e n are entered in Table 1.

The counts of phytoplankton, copepods, and nauplii are entered in Tables 2 and 3. If observations were made at more than one depth the

Table 2. Phytoplankton organisms per litre in the surface layer according to observations at Weather Ship "M", 66°N., 2°E.Gr.

Date 1949	Numbers			
	Diatomaceae	Coccolitho-phoridae	Dinoflagel-latae	Total
10. March	500	1,000	0	1,500
17. „ *)	120			120
28. „ *)	160	2,500	0	2,500
6. April	9,240	4,500	8,500	22,240
11. „	4,300	9,500	1,020	14,820
22. „ *)	3,100	8,500	1,000	12,600
28. „ *)	6,100	10,000	1,000	17,100
5. May *)	3,060	10,260	2,520	15,840
12. „	8,500	28,000	40	36,540
19. „ *)	7,540	22,000	4,000	33,540

*) An asterisk indicates observations from 0 m., otherwise the numbers pertain to depth of maximum concentration.

data apply to the depth of maximum population. In the case of the copepods and the nauplii the values from the two vertical hauls above 100 m. have been combined. The phytoplankton data have been placed at my disposal by cand. real. P e r H a l l e r - N i e l s e n, the zooplankton data by mag. sc. O l e J. Ø s t v e d t. I wish to express my thanks to these two and to Mr. S æ l e n for their kindness.

No observations of the incoming radiation were made at the Weather Ship, but approximate daily values have been computed by means of M o s b y' s formula:—

$$\bar{I}_0 = 0{\cdot}026\ (1 - 0{\cdot}075\ \bar{C})\ \bar{h}\ \text{(g. cal. cm.}^{-2}\ \text{min.}^{-1}\text{)}$$

where $\bar{C}$ is the average cloudiness on the scale 0 to 10 and $\bar{h}$ is the average altitude of the sun. The latter can readily be computed for every day for the latitude of the Weather Ship, and the cloudiness is obtained from the meteorological observations. From the values of I_0 that have been determined in this manner daily values of D_{cr} have been found and have been smoothed by forming overlapping 5-day averages.

Measurements of transparency were not made, but at an oceanic

Table 3. Numbers of copepods and nauplii from vertical hauls between 100 m. and the surface at Weather Ship "M", 66°N., 2°E.Gr.

Date 1949	Numbers		Total	Date 1949	Numbers		Total
	Copepods	Nauplii			Copepods	Nauplii	
2. March	1,319	0	1,319	23. April	11,220	10,190	21,410
9. „	2,339	0	2,339	27. „	3,674	1,005	4,679
16. „	2,758	0	2,758	4. May	2,313	2,730	5,043
7. April	1,644	85	1,729	18. „	39,131	10,550	49,681
14. „	4,606	3,480	8,08-	25. „	42,103	9,370	51,473

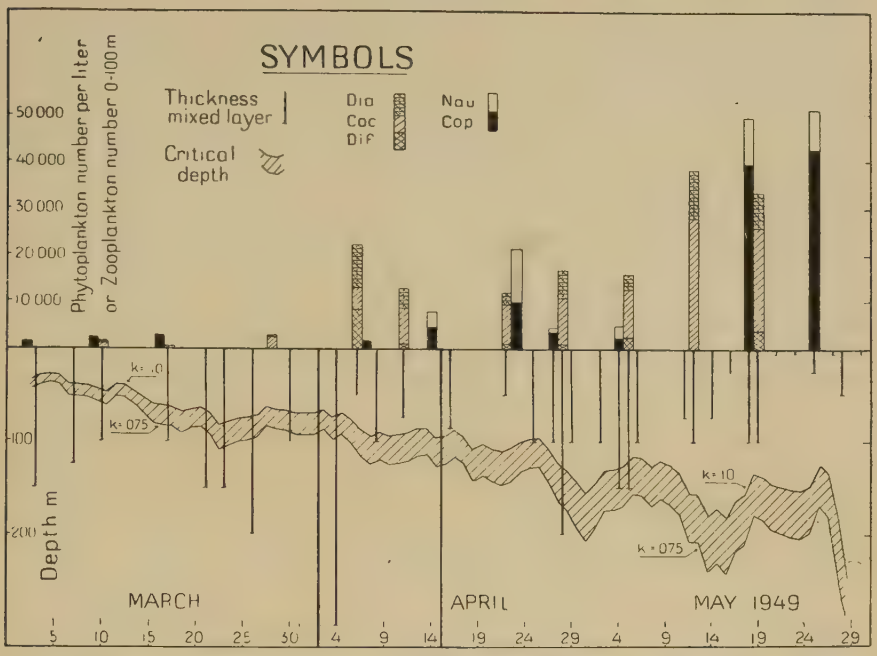


Figure 2. Results of observations at Weather Ship "M" (66°N., 2°E. Gr.). The symbols are explained in the graph, where the following abbreviations have been used:— Dia, Diatomaceae; Coc, Coccolithophoridae; Dif, Dinoflagellatae; Nau, Nauplii; and Cop, Copepods.

locality the coefficients of extinction of total energy may be assumed to lie between 0·075 and 0·10 (Jerlov, 1951; Sverdrup *et al.*, 1942, p. 107). According to Jerlov the value 0·075 is probably the more correct. It should, however, be borne in mind that the value may vary from day to day, and that it probably increases as the season advances.

All variables are presented graphically in Figure 2. In the lower part of the figure the critical depth is shown, which is supposed to lie between the curves marked $k = 0{\cdot}10$ and $k = 0{\cdot}075$. These curves are based on 5-day means of D_{cr}. It is seen that the critical depth increases more or less regularly from about 30 to 40 m. at the beginning of March to nearly 300 m. at the end of May. The observed values of the depth of the mixed layer are also entered. It is seen that stabilization leading to the development of a very shallow mixed layer does not take place before the middle of May.

The graphs bring out two striking features. (1) Until the final week of April the depth of the mixed layer is greater than the critical depth, and (2) after the middle of May the depth of the mixed layer is very much smaller than the critical depth. This implies, if our reasoning is correct, (1) that until the beginning of April the phytoplankton population must remain very small, (2) that it should be expected to increase

during April and the first half of May, and (3) to increase rapidly during the last half of May, provided that the increase is not checked by the presence of grazers.

The observed amounts of phyto- and zooplankton that are shown in the upper part of the graph fully confirm these conclusions. Through March the amounts of plankton remained insignificant. On 4. April the depth of the mixed layer was for the first time smaller than the critical depth, and on the following day an appreciable phytoplankton population was recorded, but only a small number of copepods. It should be observed that the change in the depth of the mixed layer from more than 300 m. on 2. April to 50 m. on 4. April probably indicates advection of another water mass and not local stabilization. The plankton count suggests that for some time conditions for growth have been favourable in this water mass.

During the remaining part of April and the first half of May, when the depth of the mixed layer was only moderately smaller than the critical depth, the phytoplankton population remained moderately large, and did not increase systematically. At the same time copepods appeared in greater numbers, indicating that considerable grazing took place.

In the latter half of May when conditions for phytoplankton growth should be very favourable, the counts show larger numbers of phytoplankton organisms and very much larger numbers of copepods. The latter feature suggests that the development of the phytoplankton is effectively suppressed by a heavy grazing. Thus, the entire sequence of the development of the plankton of the surface layer appears to be consistent with our conclusions.

It may be pointed out that in the spring of 1949 the first increase in phytoplankton was not associated with stabilization, but with the seasonal increase of the compensation depth. Stabilization led to a second increase in population after the middle of May.

In the introduction it was mentioned that G r a n and B r a a r u d estimated the critical depth to be about 5 to 10 times the compensation depth. Since $D_{cr} \doteq \bar{I}_c / I_c k$ (Equation 6) and $I_c = I_e e^{-kD_c}$ we obtain

$$\frac{D_{cr}}{D_c} = \frac{e^{kD_c}}{kD_c} \tag{7}$$

Applying this equation to the data that are shown in Figure 2 we find that the ratio D_{cr}/D_c increases as the season advances and exceeds the value 5 after the beginning of May. A curve showing the values of the ratio could have been entered on the graph but would have complicated the presentation. It is sufficient to state that on 15. March, 15. April, and 15. May the values of D_{cr}/D_c were 2·9, 4·0, and 5·5 respectively, meaning that the results arrived at here appear to confirm the conclusions by G r a n and B r a a r u d.

The data shown in Figure 2 represent the only available series of fairly complete records which make possible an analysis of certain features of the productivity of the surface layer as related to available

light and thickness of mixed layer. It is, therefore, not advisable to place too great emphasis on the agreement between theory and observations. It is hoped, though, that the results presented here may encourage further systematic observations and collections, not only at Weather Ship "M", but at other Weather Ships as well.

Summary.

On certain assumptions a "critical depth" is defined. The depth of a mixed surface layer must be less than this critical depth if the phytoplankton population of the mixed layer shall increase. The results are applied to observations made at Weather Ship "M" (66°N., 2°E. Gr.) in March, April, and May 1949. A striking agreement is found between the hydrographic conditions and the development of the plankton communities.

References.

Fleming, R. H., 1939. "The control of diatom populations by grazing." Cons. Perm. Internat. Explor. Mer, Journ. du Cons., **14**, 2, pp. 210—227.

Gran, H. H., & T. Braarud, 1935. "A quantitative study of the Phytoplankton in the Bay of Fundy and the Gulf of Maine." Journ. Biol. Board Canada, **1**, 5, pp. 279—467.

Jenkins, Penelope M., 1937. "Oxygen production by the diatom *Coscinodiscus excentricus* Ehr. in relation to submarine illumination in the English Channel." Journ. Mar. Biol. Assoc. U. K., **22**, pp. 301—342.

Jerlov, N. G., 1951. "Optical Studies of Ocean Waters." Rep. Swedish Deep-Sea Exp. 1947—1948, **3**, 1, pp. 1—69.

Pettersson, H., H. Höglund, & S. Landberg, 1934." Submarine daylight and the photosynthesis of phytoplankton." Oceanogr. Inst. Göteborg, Meddelanden, No. 10, 17 pp. (Göteborgs K. Vetensk. Handl., 5. ser. B.)

Riley, G. H., 1942. "The relationship of vertical turbulence and spring diatom flowering." Journ. Mar. Res., **5**, pp. 67—87.

Sverdrup, H. U., M. W. Johnson, & R. H. Flemming, 1942. "The Oceans." Prentice Hall, New York. 1087 pp.

A Water-Sampler for Biological Purposes.

By

E. Aabye Jensen and **E. Steemann Nielsen.**

THE water-samplers generally used by oceanographers for collecting water samples from various depths in the sea are not usually suitable if the organisms in the water sample are to be kept alive. This is due to the fact that the water-samplers are made of metals which give off poisonous ions to the water. The larger the interior metallic surface of the water-sampler the less suitable the sampler will be for biological purposes. The insulating K n u d s e n sampler is thus particularly unsuitable, on account of the large number of internal metal cylinders.

On the other hand the so-called M e y e r water-sampler, presumably the simplest type of water-sampler used, which consists of a glass bottle with a cork stopper, and a weight suspended below, can be used for biological purposes, but only at depths not exceeding about 15 metres. The bottle is opened by a sudden jerk on the lowering line, which is attached to the stopper. After removal of the stopper a safety cord attached to the lowering line and to the bottle prevents the latter from sinking.

At depths exceeding about 15 m. it is impossible to remove the stopper from the M e y e r water-sampler, and other types of water-samplers must be used. For the purpose of collecting water samples from greater depths for bacteriological use a number of different water-samplers have been designed (see Z o B e l l 1946). For determination of the production of organic matter in the sea these water-samplers are not very suitable; amongst other things, they are too small.

For the investigations on photosynthesis in sea water performed by means of the radio-active carbon isotope C^{14} on board the Danish research vessel "Galathea" during an expedition round the world (see S t e e m a n n N i e l s e n 1952), water samples of 300 ml. from the phytoplankton zone were used. A water-sampler with a capacity of 500 ml. for use to a depth of 125 m. was therefore designed (see

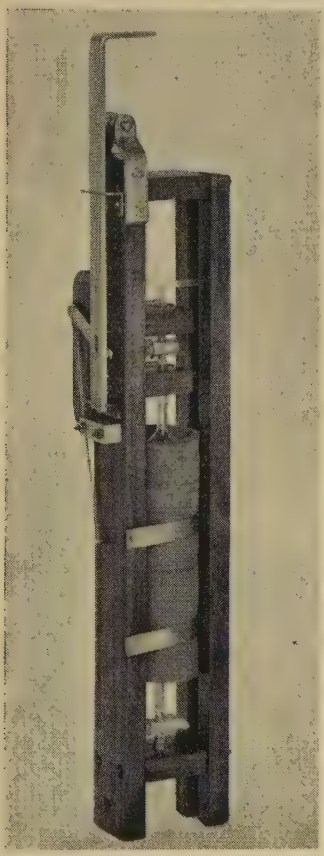


Figure 1.

Figure 1). This water-sampler is so constructed that the water sample collected is never allowed to get into contact with metal. Apart from two connexions of plastic tube, all the parts of the water-sampler which come into contact with the water sample are made of pyrex glass.

This water-sampler has now been in use for nearly two years and has proved to be sturdy and reliable in all kinds of weather. It consists of an evacuated glass container secured in a teak carrier. The sampler is opened by a messenger which operates a valve when it has been lowered to the desired depth. Evacuation is not absolutely necessary except at small depths at which the water-sampler will not otherwise fill completely with water. Evacuation is, however, convenient at greater depths also, as otherwise considerable supersaturation of the water sample with air will occur. It should be mentioned that a similar supersaturation will occur in the M e y e r water-sampler when used at depths of 10 or 15 metres.

The sampler is lowered from a standard hydrographic winch, though any winch with wire which can be used for ordinary hydrographic work is suitable. No provision has been made for attaching several water-samplers to the wire at the same time as the relatively small depths at which the samples are to be collected do not justify such an arrangement. It is convenient, however, to use a separate water-sampler for each depth at which samples are to be collected.

While being hauled to the surface the sampler communicates with the sea through the glass cock which is opened when the messenger strikes the operating mechanism. As the bore of the cock is only 1·5 mm., the exchange of water between the sampler and the surrounding water while the sample is being hauled up is minimal: for the purpose for which this water-sampler is designed, it is negligible.

Description of 500 ml. Water-Sampler for Biological Purposes.

The principal part of the apparatus (see Figure 2) is a cylindrical container of pyrex glass with a capacity of 500 ml. (1) (dimensions about 60 mm. × 220 mm.; thickness of wall about 2 mm.). The ends are tapered, and at either end a sturdy pyrex glass cock (2 or 4) is fitted (bore about 1·5 mm.); both ends are connected by a short length of

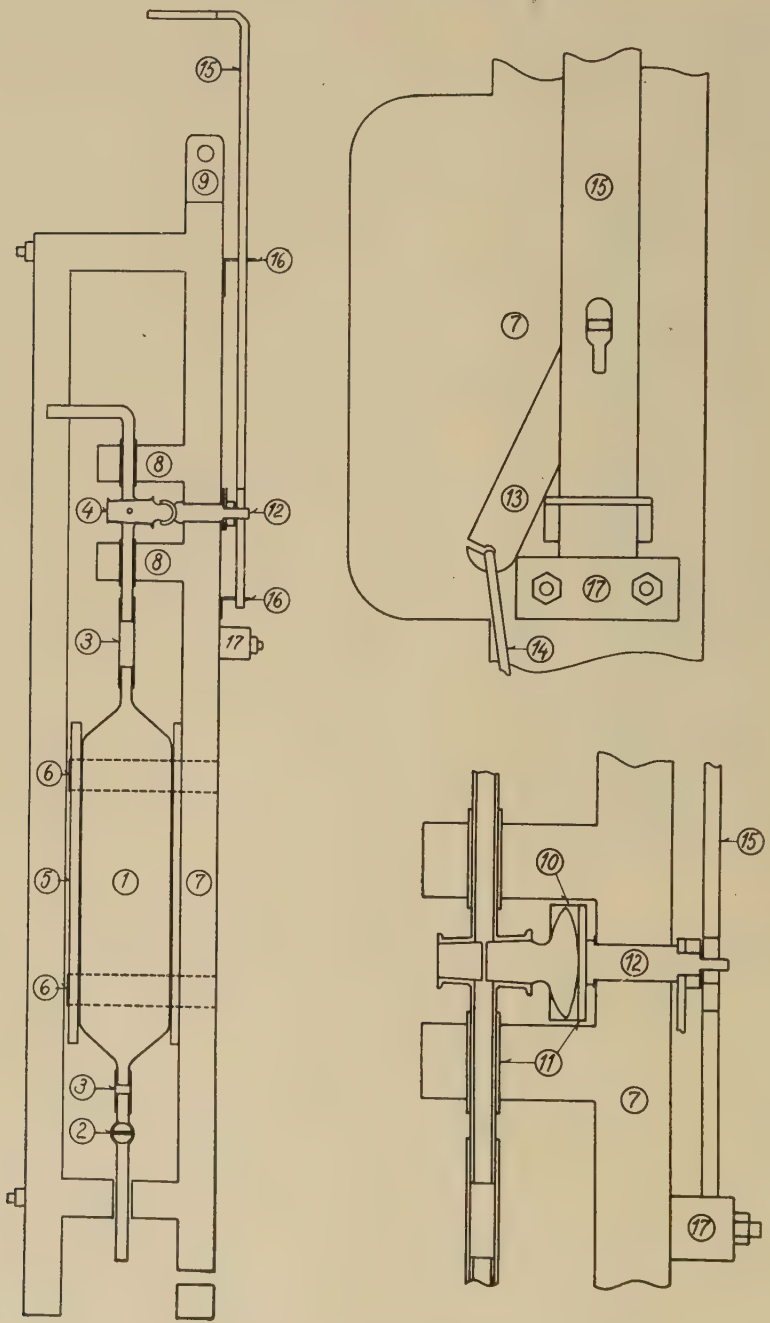


Figure 2.

flexible plastic tube (3) to the container (1). A protecting jacket (5) consisting of 6 mm. thick sponge rubber is fastened by wide rubber bands round the cylindrical part of the container, which, with this protecting sheath is secured by two transverse metal bands (6) in a teak frame (7).

The cock (4) attached to the upper end, i.e., the main cock, is secured to the frame near its upper end by two supports (8) of teak with rubber bushes. The top of the frame also carries an ordinary shackle (9) for attaching to the eye of the wire.

The water-sampler is prepared for operation by opening the main cock, which is turned through an angle of 90°. The cock is turned by a broad metal fork (10) with a rubber lining (11) which grips the lever handle of the cock. This fork is attached to the end of a shaft (12) which is passed through the frame in line with the axis of the cock plug. The shaft can turn in a bearing in the frame and carries, outside the frame, a cross arm (13) which is actuated by a tightly stretched rubber band (14). The extreme end of the shaft is flattened so as to fit into a slot in a flat operating rod (15) which slides in guides (16) attached to one side of the frame. When the operating rod is in its top position and the flattened end of the shaft fits into the slot, the main cock is closed and the rubber band tightly stretched. The operating rod is extended beyond the shackle and at its top it carries a fork at right angles to the rod and engaging the wire.

The mechanism is operated by a messenger, which strikes the fork on the operating rod and pushes the latter downwards, thereby causing the flattened end of the shaft to pass clear of the narrow slot into a larger aperture in the rod. The pull exerted by the rubber band now causes the shaft and main cock to turn until the cross arm, after having turned through an angle of 90°, strikes a stop (17). The main cock is now open and the container can fill with water. To make the container fill up completely it must be evacuated before being lowered into the water. The cock (2) at the bottom of the container is used for the evacuation and for drawing off the water sample. All metal parts are of brass.

The bottom part of the teak frame is provided with a hole through which a short length of rope carrying a shackle is passed. The water-sampler is weighted by a suitable lead weight (usually of 5 kilogrammes) attached by this shackle.

References.

Steemann Nielsen, E., 1952: "The Use of C^{14} for the Measurement of Organic Production in the Sea." J. Cons. Int. Explor. Mer, **18**, No. 2.

ZoBell, C. E., 1946: "Marine Microbiology. A Monograph on Hydrobacteriology." Waltham, Mass.

Theory and Practice of Marine Fishery Management.[1])

By

Martin D. Burkenroad,

Institute of Marine Science, The University of Texas,
Port Aransas.

I. Fishery Management as Political Economy.

The management of fisheries is intended for the benefit of man, not fish; therefore effect of management upon fish-stocks cannot be regarded as beneficial *per se*. Nevertheless, economic benefits of management depend on biological response to differences in mode of exploitation, the theory of which is fundamental to an understanding of fishery economics.

1. The theory of the maximum equilibrium yield.

When the amount of fishing to which a particular fish-stock is subject increases, the mass of the fish-stock is expected to become less than it would otherwise have been. Therefore, other things being equal, the more fishing the less can be harvested by a given amount of effort.

As the density of the stock is reduced by fishing, the degree of saturation of the range which supports the fish should become less, and the particular stock would thus be expected to be able to add more to itself in a given period of time than it did when only lightly fished. If a given moderate harvest were continued year after year, the stock should, under simple ideal circumstances, decline less and less rapidly, finally attaining a new equilibrium at a mass less than that of the virgin stock. Lessened abundance may thus be no more than a sign that the resource is being utilized.

However, the ability of a stock of fish to reach equilibrium with a fishery must have a limit; that is, there must be a degree of reduction

[1]) References and details of evidence and reasoning, omitted here to improve the coherence of an exposition difficult to condense, will be found in Publ. Inst. Mar. Sci. II, 1 (1951): 177—212.

in stock-density below which the rate at which the stock can replace itself ceases to increase with decline of stock-density. Until this point is reached, the catch with which the stock could attain equilibrium would be expected to increase with fishing. Additional sustained effort beyond the critical level should then begin to reduce the sustainable catch.

"Overfishing" might thus be defined as the condition in which an increase in fishing effort must result in a reduction (relative to what would otherwise have obtained) not only in density of stock but in total weight of catch.

If a fish is in sufficient demand, the price which society will pay for it may rise enough with scarcity to permit the fishing effort to be sustained even though the stock has been reduced below its level for maximum equilibrium yield. Since the same equilibrium poundage might have been produced by less effort, before the stock was reduced below the critical point, the undirected interplay of social forces can result in a waste of effort which could be saved by management. If fishing continued profitable until the stock was reduced below the level at which it could maintain equilibrium with irreducible causes of mortality other than fishing, a commercial fishery could cause extermination (as may be possible for whales and anadromous fishes, although it is doubtful if extermination for profit could be effected in the case of most marine fishes and invertebrates).

Reduction of a stock below the level for maximum equilibrium yield thus has results which are clearly definable in terms of wasted effort. However, the social benefits of saving this effort by management are not so easy to demonstrate, as will be shown below.

2. Possible disadvantages of management.

A. *Overfishing as the result of dietary prejudice.* Taking the North Sea bottom fishery as providing the best-attested case of a marine fish-stock driven beyond the biologically critical point, it has still to be considered that equally nutritious fish of other kinds (as herring) can be supplied to the north European market at lower cost. The high value placed on the demersal varieties, which permits them to be overfished, thus appears to result from a culturally-conditioned preference which can be termed rational only within a strictly limited frame.

Such tastes are not necessarily immutable. It might be supposed that the more expensive become cod, plaice, and haddock the greater the extent to which cheaper fish would be substituted for them; and that in time the *de facto* change in habits of consumption might be confirmed by modification of cultural ideals. If such change in preference among sea-foods would be facilitated by overfishing certain demersal stocks, the benefit to society might conceivably turn out in the end to be greater than would be obtained by management of the North Sea trawl fishery.

Further, a preference for one sort of sea-food rather than a cheaper equivalent is not a particularly costly irrationality, as such things go.

The consumption of animal proteins of all kinds in quantities greater than is required for physiological well-being wastes effort to a much greater extent than does the overconsumption of particular fish. It is therefore legitimate to ask whether public expenditure directed to correction of effects of the minor irrationality might yield greater gains if otherwise applied.

B. *Relation of overfishing to the development of unused resources.* Although improvements in the technique of capture and marketing may cause increased waste of fishing-effort when the stocks to which they are applied are already overfished, they may prove applicable elsewhere with a resultant overall gain, as presumably in the case of Vigneron-Dahl rig. Public management of fisheries aims toward stabilization, with equitably distributed benefits for all; and even if developing improvements were not actively repressed toward this end, the conditions created by management may to some extent discourage initiative and enterprise.

The situation might be put in this way. If a stock has been overfished, it follows that its maximum equilibrium yield is insufficient to satisfy demand; *i.e.*, the resource is in any case inadequate. If matters are allowed to take their course, the rapidly rising prices resulting from declining total yield should facilitate the development of technical means to transfer the excess of demand to other resources — to a greater extent than if the rate of decrease in adequacy of supply were slowed by management. Thus, localized restriction of excessive fishing might hamper the utilization of marine resources in general; at least so long as there are elsewhere little-used stocks capable of being profitably exploited, once sufficient attention has been paid to the development of means to fish and sell them. Antarctic euphausiids will in time to come probably contribute a staggering equilibrium yield directly to human nourishment; and rapid decrease in the supply of choice North Sea fish might conceivably help to bring about such development at a sufficiently increased rate to make up indirectly for the effort meanwhile wasted in North Sea demersal overfishing.

3. Conditions in which management is justified.

The above arguments against the reality of gains from management depend upon the difficulty of predicting the social consequences of a given course of action, and the inefficiency of any social organization yet developed. Although they may be sound, these arguments weigh intangibles against the measurable advantages of management in cases of overfishing; hence comparable intangibles which might favour management ought also to be considered. One of far-reaching importance is an increase in the rate of accumulation of organized knowledge concerning deliberate adjustment of society to its environment. Such experience might perhaps at present be gained and objectively recorded most readily in connexion with efforts at fishery management.

On the whole, if it can be shown that in a case at issue fishery management ought to be expected to result both in increased rate of

acquisition of basic knowledge and in a nett economic gain, experiment is probably justified despite possible indirect disadvantages. But it is by no means so easy to meet these conditions as might be thought.

II. Tangible Nett Gain from Fishery Management.

1. Economic effects of biological change.

It seems difficult to devise satisfactory concrete means to measure differences in the nett value of a pound of fish to society. Price to fishermen is not necessarily a valid index of demand. Even if it were, a correction has to be made for changes in ratio of the price to the costs of production; but this is complicated by the fact that the costs are at the same time part of the income of the society. And even an acceptable index of value coupled with a precise knowledge of the relation of catch per unit effort to catch would still not go far toward permitting prediction of the intricate effects of change in total catch on costs and price per unit of catch.

Any reasonable index of tangible nett value would presumably assign higher rank to a given catch fetching a given price (in monetary units of constant purchasing power), the less effort it had cost. But if increase in catch per unit effort had been obtained by a sacrifice of potential catch, as would be the expected result of fishery restrictions at stock-densities above those for maximum equilibrium yield, resultant improvement in value per unit of catch might be so offset by the reduction in number of units caught as to reduce the total value of the catch. Even if price per pound increased rapidly with size of the individual fish caught, it would depend a good deal on the terms of the index of value whether the sacrifice of potential catch would seem justified. Thus, the gain from management of a stock which has not been overfished is an extremely difficult issue. Since it is at present economically impossible to overfish most marine fishery stocks, assured evaluation of tangible nett gain from management seems difficult except in the relatively infrequent (though, naturally, conspicuous) cases in which there is reason to think that the unrestricted catch would under present conditions be greater than sustainable and that the stock is near or below the level for maximum rate of replacement under the prevailing fishery-independent conditions of the environment.

Even in such cases, the economic effects of management are likely to be uncertain. For example, regulation of the Pacific halibut fishery has resulted in reduction of opportunity to fish at times of densest aggregation of the stock, in frozen storage of much of the catch, and in part-time idleness of boats and gear. This presumably reduces the profits of producers and handlers or increases the costs to consumers, in the same way as would the waste of effort if unregulated fishing (controlled only by demand at the concomitant costs) caused reduction of the stock below the critical level. It is not a foregone conclusion that such economic calculations would seem favourable to halibut management,

even if present stocks were below the level for maximum equilibrium yield (and since, as will be shown below, it is not certain that the halibut stocks ever were reduced to critical density, tangible nett gain from halibut management is doubly doubtful). This is not to say that nobody has benefited, but if benefits were obtained at the consumer's cost, questions of the public interest have to be considered.

2. Prediction of the biological effects of fishing.

Whether or not the economic value of a change in fishing can be reliably predicted or evalued, it seems clear that a rather precise estimate of the biological resultant would be prerequisite to such economic computations. Difficulties in foreseeing or identifying the causes of biological change arise from three sources. First, the change in a stock of marine fish can be determined only by indirect means, and even the most elementary data are not only hard to obtain but hard to interpret unequivocally. Second, change in one living component of a complex ecosystem may have repercussions in other parts of the system, such that the economically important biological results of a particular fishery cannot be deduced from data so limited as those usually available. Third, environmental circumstances of the ecosystem may change independently of fishing, sometimes even in ways evidenced only by their effects on fishery stock; so that the attribution of observed change in stock to that in variables under human control may be mistaken.

A. *Interpretation of data.* The biological interpretation of fishery statistics is beset with numberless technical difficulties so varied and so well concealed as to discourage other generalization than a reminder that science advances through search for inconsistencies and their causes, and for alternative interpretation of observations.

An example of the ease of misinterpretation and of the devious routes which lead to its recognition may be drawn from the classical studies of Pacific halibut. The rate of tag return on Area 2 fishing grounds in the mid-1920's indicates a yearly catch amounting to two-fifths of the average marketable stock on hand. The stock magnitude thus defined is consonant with the conclusion that the striking historical reduction in abundance was caused by fishing.

However, comparison of the ratio of catch per unit effort to estimated stock magnitude on Area 2 with that on Area 3 reveals a surprising discrepancy. Search for an explanation of this discrepancy leads to realization that localities in which halibut were tagged were selected according to the local intensity of fishing. On Area 3 the fish marked were preponderantly adults which redistributed themselves freely over the range; so that the manner of initial distribution of the tags probably had little effect on the rate of return. But on Area 2 the marked fish were immature and therefore sedentary; hence selection of the more heavily fished banks for tagging must have resulted in a disproportionately high rate of return.

Reasonable allowance for unrepresentative distribution of Area 2

tags reduces the estimate of overall fishing-mortality rate in the mid-1920's from two-fifths of the average stock per year to only one-fifth. On the basis of calculations from the revised rate, it may be questioned whether the Area 2 catch was sufficient to account for the decline of abundance or to drive the stock below its level for maximum equilibrium yield under the environmental conditions prevailing.

A further example of the difficulties of interpretation, drawn from the same source as the preceding, concerns the significance of change in catch per unit effort. The halibut fishery is restricted to hook and line. The catch per set of hooks depends not only on the abundance of marketable halibut but on that of other organisms which steal the bait or pre-occupy the hooks. Consequently, an apparent reduction in abundance of halibut might be caused by an increase in the abundance of, let us say, rock-cod. Such a change in relative abundance of competitors for the bait might be wholly independent of the fishery; but it might also be fishery-dependent, if the halibut fishery is such as to favour the unwanted forms. In the latter case, a relatively slight change in magnitude of the stock of halibut might entail a much larger change in the catch per unit effort with hook and line — which would certainly complicate the estimation of equilibrium yields.

Abundance of fishery stocks is usually tracked in part at least from the relative catch per unit effort. This requires reduction of actual fishing effort to a standard efficiency. Change in efficiency of the effort may in part be *real*; that is, improvements in gear and methods permit capture of a larger proportion of the fish present on the area fished. Real differences in efficiency are often standardized by direct comparison of differing methods at the same time and place, and by use of averages on the assumption that weather-changes during the period were unsystematic. However, important differences in efficiency of effort may be not real but *apparent*; that is, the partitioning of the stock between fished and unfished areas may change, even though the rate of capture of fish present in the area fished is the same. Apparent efficiency may be subject to systematic change and is often exceedingly difficult to estimate. Part of a previously available stock may shift out of the range of the fishery; or a decline in the ratio of prices to charges on invested capital (as in deflation) may, while eliminating part of the fishing-fleet, force the remainder to fish harder and therefore less selectively.

In connexion with the latter possibility, parallelisms in catch per unit effort of fisheries thought to tap independent stocks are of interest (though particularly hard to interpret). For example, the occurrence of a low catch per unit effort in times of economic depression seems frequent enough to suggest the possibility of significant uncorrected economic influence on efficiency; and such correlations as that between catch of haddock per standardized unit effort on Georges Bank and landings per day's absence of North Sea sail trawlers, 1919—1935 ($r_s = +\cdot 81$) are not necessarily either fortuitous or referable to parallel changes in magnitude of the respective stocks.

B. *Effects of fishery-dependent environmental change.* The interdependence of fisheries based on different components of the same ecosystem is obvious when the relationship between the stocks is that of predator to prey. For example, the valued fish *Cynoscion* and *Sciaenops* of the southern United States feed to considerable extent on the currently most valuable fishery resource of the region, shrimp. Calculations suggest that the consumption of shrimp by the fish is on the order of the catch by man; and that human predation is so intense that the annual catch of shrimp may be considerably larger than the average standing crop. The equilibrium yield of shrimp must thus depend to a considerable extent on concomitant changes in the stocks of fish, and changes in it cannot be predicted from data on shrimp alone.

A more complex example of possible effects of fishery-dependent change may be taken from the North Sea. The increase in abundance of demersal fish during the first war has been used as a measure of the rate at which the equilibrium yield would change if fishing were regulated. The maximum equilibrium yield and the corresponding stock magnitude so calculated (on the assumption that rate of replacement per unit of stock is a straight-line function of total stock) are consistent with the conclusion that the North Sea demersal stock was already overfished before the first war. However, if these calculated rates of equilibrium yield are re-applied to the changes in abundance observed during and in the first few years after the war, both the increase and the decline of the stocks seem too rapid[1]).

[1]) If North Sea demersal landings in 1913 were around 380,000 tons, and if this was around 40 per cent. of the average stock then on hand, the stock must have been around 950,000 tons. Hence, if the 1919 stock averaged 1·9 times that of 1913, it must have been around 1,800,000 tons. The stock would then appear to have gained 850,000 tons in the six-year period. Around 1,760,000 tons were removed as landings during the same period. Catch plus increase left in the water would thus have been some 2,600,000 tons, equivalent to an average rate of addition and replacement around 430,000 tons per year. However, it seems to be agreed that the 1919 stock was far above the level for maximum equilibrium yield. Therefore, the rate of addition during some of the war years should have been far above the average of 430,000 tons.

However, there seems no evidence that North Sea demersal landings were ever much above 400,000 tons per year prior to 1920 (cf. K y l e' s estimate of the catch of plaice in 1893—1894), or that the demersal stocks were already seriously overfished before 1906. Therefore, 400,000 tons per year would be about the *maximum* rate of addition to be expected on the basis of pre-war performance (i.e., either 400,000 tons was more than the maximum equilibrium yield, or the stocks at the beginning of the first war had not been reduced below the critical level and should therefore have added progressively less than 400,000 tons per year as population-density increased).

If landings per day's absence in 1923 were only 46 % of those in 1919 and if the 1919 stock averaged 1,800,000 tons, the decline in marketable stock, 1919—1923, might be estimated at more than a million tons. The catch from mid-1919 to mid-1923 amounted to some 1,820,000 tons, leaving only some 800,000 tons for total replacements during the four-year period; or an average of 200,000 tons per year. However, the range in density of population was about the same in 1919—1923 as in 1913—1919. Therefore it might be thought that the average rate of addition and replacement should (*ceteris paribus*) have been much the same in these two periods. On this basis, the rate of replacement immediately after the war was less than half of what might have been expected from the increase in abundance during the war; and it was also appreciably

Consideration of this inconsistency leads to the question whether reduction of density of marketable stocks by fishing ought not to be expected to lead to accumulation of suitable prey. In this case, sudden relief of fishing mortality might have enabled the marketable North Sea demersal stocks to expand beyond what the rate of replacement of their food-stocks could sustain, at the expense of the accumulation. Having thus over-run the food supply, the war-increased stocks of marketable fish would perforce decline for a while at a greater rate than would otherwise be expected, and so on until the oscillations had re-established the changing equilibrium of predator with prey. Thus, the high rate of change in abundance of marketable fish during and immediately after the first war does not necesssarily provide critical evidence that the pre-war stocks were already below the level for maximum equilibrium yield. In this case, data from the control case afforded by the second war would seem to be required for demonstration that the marked decline in both abundance and yield during the period 1925—1938 was a sign of overfishing rather than of fishery-independent environmental change in, say, phosphorus supply.

The ultimate problems of fishery-dependent change appear when limit of yield is considered without reference to particular kinds of organic matter. Neglecting costs as well as prices, maximum yield must depend on the rate at which limiting nutrient elements removed from the ecosystem can be replaced from outside. However, if nutrient recently released by the system's own metabolism were an important part of what is available to its producers (*katabolic* ecosystems, in contrast *to anabolic* ones in regions of upwelling), the ability of the system to support standing crops might decline rapidly with harvesting, if the organisms removed were important in maintenance of the system's katabolic rate.

The energy demand (hence, phosphorus demand) of the North Sea biomass seems likely to be much greater than can be met by the income of phosphorus from outside the region, which suggests that rate of photosynthetic production in the North Sea may depend in large part on turnover of the store of phosphorus on hand. The stock of marketable demersal fish per unit area of Georges Bank seems greater than that in the North Sea at comparable rates of yield, to about the same extent as is the probable rate of photosynthetic production. This is consistent with the hypothesis that abundance of North Sea demersal fish at a given rate of catch is closely related to rate of basic production.

---

less than what might have been expected from the balance of abundance and yield in 1906—1913 (on the assumption of a straight-line relation between the rate of replacement per unit of stock and the stock-density), even if the 1919 stock was near the maximum which the region could support.

It should be noted that even if landings of haddock per day's absence had declined no more rapidly in 1919—1923 than did the remainder of the catch, the rate of replacement during the period would still seem appreciably too low. Therefore the poor haddock brood-years of 1921—1922 (which might themselves conceivably be the expression of fishery-dependent change in environment) can probably not be thought to be the whole basis for the over-rapid decline in landings of all kinds per day's absence.

Reduction in abundance of marketable demersal fish seems likely to result in appreciable reduction of the respiratory rate of the benthonic fauna (which would presumably increase in age and individual size even more than in mass). Therefore rate of turnover of the North Sea phosphorus store, and with it rate of basic production, might decline to a significant extent with increased fishing. In terms of ability of the system to support a yield of marketable bottom fish, there would apparently be expected a reduction in availability of food appropriate to the young, while the relatively increased quantity of large benthos might be more than could be utilized by the fishery-limited marketable sizes . Therefore the rate of individual growth of a given stock of the young fish might be slowed instead of improved, as the density of the marketable stock was reduced by fishing.

The outcome of these complicated speculations is the question, with what accuracy the curve of equilibrium yield against equilibrium stock-density of a particular component of a complex ecosystem can be deduced or extrapolated from ratios observed at stock-densities limited in range or not in stable equilibrium. In practical terms, it seems possible that maximum density of North Sea demersal stocks might be considerably higher at the final equilibrium than has been estimated from the effects of war; and also that economic gains from moderate restriction of North Sea trawling might be even greater than has been thought (a result which, it should, however, be emphasized, might be quite inapplicable to a region in which basic production is less dependent on internal katabolism, as Georges Bank).

C. *Identification of fishery-independent changes in equilibrium yield.* Estimation of nett gain from management requires the distinction of changes in abundance which would have come about regardless of fishery regulation from those dependent on the restriction. The criterion of overfishing is fishery-caused decline in both abundance and yield; but if unfavourable fishery-independent changes in the environment are simultaneously affecting the stock, it becomes difficult to say whether a higher rate of fishing-effort would necessarily have reduced the yield.

For example, the highest average annual catch during early years of the Area 3 Pacific halibut fishery, 1915—1926, was 18 million pounds; and even during the later pre-regulation period 1924—1930 the maximum was only 30 and the average 27 million pounds. Between initiation of the fishery and application of the quota-system, abundance of the stock is believed to have declined from an initial level well above any subsequently attained, to a final level far below the abundance regained after quotas were imposed.

The peak of post-regulation availability in this fishery was attained in the early 1940's, when catch per set of gear rose from 121 lb. in 1940 to 151 lb. in 1944, despite a rather steady level of catch averaging over 27 million pounds per year. The question raised by these data is, why a stock of moderate magnitude able to increase during the 1940's even though subjected to a drain of over 27 million pounds per year should previously have declined from high to low magnitude in response to a

smaller catch. The simplest explanation would seem to be that fishery-independent environmental conditions became much more favourable after 1930.

But if natural changes were so extensive, there is no present means to be sure that yield would not have increased if the rate of catch had been higher than was actually sustained, even in the early 1930's. This possibility is emphasized by the striking decline of Area 3 catch per set after 1944 (in correspondence with previous prediction based on the view that the decline of the stock in 1915—1930 was chiefly independent of fishing, and that the conditions responsible for this decline might reappear despite regulation of fishing).

The suggestion that such part of the increase of abundance of Pacific halibut as may have resulted from management was obtained by a more-than-commensurate sacrifice of potential catch seems applicable to Area 2 as well as Area 3. Catch per standard set of gear on Area 2 was closely parallel to that on Area 3 during the period of record, 1915—1948. The coefficient of correlation (by rank difference, r_s) is + ·88 both for the 16 years before regulation began and the 18 years afterward. The scatter of points around the regression line of catch per set on one Area against that on the other is remarkably compact over a wide range of catch per set.

This striking parallelism might indicate that catch per set on Area 2 was governed chiefly by the same factors as on Area 3; in which case, if change in Area 3 availability was chiefly independent of fishing, the same would apply to Area 2. Alternatively, the parallelism might indicate merely that Area 2 was kept fished down to the same level of profitableness as Area 3, regardless of what controlled the latter abundance. In this case, however, the ratio of Area 2 catch or effort to that on Area 3 should have shown an appreciable trend, unless the two stocks preserved much the same relation to their respective levels for maximum equilibrium yield (e.g., if one stock were below its level for maximum equilibrium yield while the other was above, a rise in abundance of the former should entail an increase in the catch required to prevent further increase in abundance, whereas the reverse should be true of the latter). Since the ratios of catch or effort on the two grounds show no significant trend between the mid-1920's and the mid-1940's, it would appear that if the one stock was not overfished the other may not have been either. Hence, even if Area 2 abundance was chiefly controlled by fishing, the doubt of overfishing which has been raised for Area 3 may be extended to Area 2.

III. Discussion

(the experimental method in marine fishery biology).

It is quite difficult to doubt that North Sea demersal stocks have been or can under present economic conditions be overfished. In contrast, the view that Pacific halibut has been overfished has been shown to be quite open to question. Analysis indicates that it is the repeated

arbitrary restrictions and renewals of fishing caused by the wars which supply crucial evidence in the North Sea case, lacking for Pacific halibut.

These repeated North Sea changes in fishing have somewhat the effect of a controlled experiment, from which may be estimated the degree of probability that other factors than fishing were important. The experiment in halibut restriction is in contrast uncontrolled, and supplies no evidence that changes in the stock observed before 1930 would have been repeated if pre-1930 fishing had occurred under the environmental conditions existing in the decade after 1930.

Statistically acceptable evidence whether fishing was the only variable which changed significantly might apparently have been obtained for halibut by appropriately pre-scheduled alternation of periods of increase and decrease of quotas. The risk of tangible nett loss from use of such inductive methods would seem less than that from the unverified assumption that the halibut stocks were seriously overfished.

The nature of productive relationships within complex ecosystems seems to be such that the equivalent of controlled experiment might always be required for what may be termed *biologically effectual exploitation* (i.e., that mode of exploitation which will produce a prescribed biological result). Appreciation of the inherent limitations of deductive fishery science, and of the varied advantages obtainable by design of regulations in accordance with the principles of experimentation, may be expected to increase with critical analysis of the results claimed for management.

Acoustical Aspects of some Indonesian Fisheries.

By

J. Westenberg,
Zoological Station, Den Helder.

1. Introduction.

In several fisheries the achievement of successful results depends greatly on the behaviour of the fish. Stimuli of several kinds seem to incite the fish to act in a way of which advantage can be taken by able fishermen. In such cases the fishing gear must be adjusted to the behaviour of the fish in question, and it is to be expected that some of the problems which arise have their origin in the field of the physiology of the senses. For example, a more detailed knowledge of the stimuli which affect fish might be of help in designing more effective fishing gear and techniques.

In general, we should expect to find that several kinds of stimuli influence the behaviour of fish in their natural environment, viz., chemical, optical, acoustical, and tactile. In the present paper a number of Indonesian fishing methods are discussed, with special reference to the part played by acoustical stimuli. Although electrical stimuli have proved to be of importance in recent technical developments, these are not taken into account here, since they do not play a part in the local methods applied in Indonesia.

2. Sound and fish.

Sound is transmitted through water with much less absorption of energy than through air. This should favour the possibilities of communication and orientation in aquatic life.

The velocity of sound in sea water has been found to vary with temperature, salinity, and pressure, but averages about 1500 metres per second. Sound travelling through water is reflected by solid bodies as well as by the surface (or by air bubbles or gases present in animal bodies).

A marine acoustical survey (K n u d s e n *et al.*, 1948) has revealed that the ambient noise in the sea comprises a considerable range of frequencies. The energy of this sound appears mainly to depend on the

state of the sea, and the movements of a ruffled surface can hence be regarded as the principal source of sound in the sea. Apart from this noise of physical origin, animal sounds can also be heard in the sea. Among these, the sounds emitted by fishes are of special interest to the present subject.

In general, the sounds of fishes may be classified in three main groups. The first group comprises those emitted by special sound-producing organs. In some species (e.g., kerong-kerong, *Therapon theraps* C. V.) the sounds are loud and piercing (P i e t e r s, 1933), while in others (e.g., the layang or round scad, *Decapterus russelli* Rüpp.) they can only be perceived by well trained experts (Z a n d s t r a, private communication).

In the second group we include the rushing sounds made by the fish swimming. These originate in a way similar to the so-called aeolian sounds that can be heard when the wind blows through a pine forest.

In the third group we may put the vibrations that must arise from the beating of the tail in fast-moving fish. Even with small fish, the frequencies are too low to be perceived by the human ear.

At several fishery centres there are experts who rely on sound for locating and even identifying schools of fish swimming too deep to be seen from the surface. This is sometimes done by placing the ear against the inside of the hull of the boat, or against a hardwood paddle[1]) with its blade dipped in the water. For direct listening the fisherman bends overboard and holds his head under water, while in other instances diving is preferred (F i r t h, 1943; M a n o u a i n, 1941, p. 23; l e M a r e, 1946, p. 11; v a n P e l, 1938, p. 105; P r a n j o t o, 1939, p. 9). The practice of listening for fish has been reported from several centres, viz., the Thousand Islands (M a n o u a i n, 1941); Tanara and Krawang (West Java) (Z a n d s t r a, private communication); Pemalang, Tegal, and Tuban (Central and East Java) (P r a n j o t o, 1939 and private communication); Banjuwangi (East Java) (v a n P e l, private communication); Tioro Strait, south of Celebes (D j o e m h a n a, 1941), and, outside Indonesia, from Kelantan and Trengganu (Malaya) (F i r t h, 1943).

The sense of hearing in fish has for a long time been a debated question in science (P a r k e r, 1918). Conclusive proof has finally been given by P i p e r (1906), who demonstrated the occurrence of an action current in the 8th cranial nerve in pike (*Esox lucius* L.) and in eel (*Anguilla vulgaris* Turton), which lasted as long as the sound. From these results P i p e r concluded that fish respond to sounds by means of their ears (cf. P a r k e r, 1918). Further convincing evidence is mainly due to v o n F r i s c h (cf. v. F r i s c h, 1936).

In this respect it is interesting to learn that in one of the ancient Javanese fishing methods, sound is used for attracting fish. When a free-swimming school[2]) of bawal hitam (black pomfret, *Stromateus niger* Bloch) is seen near the surface, a boy jumps overboard with a

[1]) Usually made of sawu wood (chiku, *Achras zapota* L.).

[2]) Not kept in position by any palm-leaf lure-lines as described in the next chapter.

bamboo, about as long as his body, and fitted with a cross-bar near its upper end. As he floats with his arms resting over the cross-bar, he sings in a monotonous voice, uttering a prolonged "ooh". This makes the fish flock round the singer, and sometimes even jump in his face from excitement. The school is then easily encircled with a net. This method is reported from Pemalang, Japara, and Demak (P r a n j o t o, private communication).

A so-called "uruk-uruk", a shark-attracting rattle of coco-nut shells, has been described from Bunguran, Natuna Islands, by v a n H a s s e l t and S c h w a r t z (1898, p. 460).

The extent of the audible range of the ear has been examined in several species of fish, the majority of which appeared to be deaf to sounds of high pitch. The lower end of the range still needs closer investigation, as appears from the following sections.

3. Coco-palm-leaf lure-lines and similar devices.

In the majority of pelagic coastal fisheries in the Java Sea, the actual netting operations are preceded by concentrating the fish near coco-palm-leaf lure-lines, known as "rumpons". A "rumpon" consists of a rope to which coco-palm-leaves are attached. At the bottom end, the rope is secured to a bamboo anchor weighted with a stone. The other end is kept up by a float composed of a number of bamboo poles lashed together, and provided with an upright mark, enabling the fisherman to recognize his property.

The rope is usually made of the fibres of the sugar palm (*Arenga saccharifera* Labill.) or of beaten and twisted bamboo. Both are very coarse, but are remarkably resistant to sea water. The midribs of the leaves are split to produce two separate units from one leaf, the stalks being discarded. In order to attach the leaves, the strands are opened by twisting against the lay, and the split leaf is then inserted between them. This is repeated at one-metre intervals along the upper part of the rope.

A regional variation of this device is the pendant lure-line. In this type, anchor and float are connected by a plain rope, and the float is attached to another float bearing a pendant lure-line with leaves. The whole contrivance is set in water of 20 to 60 m. depth, and if fish are plentiful, they immediately gather near the rumpon, as if they had been waiting for it. Usually the fish are not abundant, and sometimes it takes as long as five days to collect a quantity of fish worth catching. The school is thenceforth fished at regular intervals with a "payang", resembling a lampara net.

Before paying out the net, the leaf-lure is hauled up a little, in order to raise the school and bring it within reach of the net. Details of the gear and its manipulation are described in the technological literature dealing with this so-called "mayang" fishery (t e n B r i n k, 1910; v a n K a m p e n, 1906, 1909, 1922; v a n P e l, 1938; v a n R o o s e n d a a l, 1910). In clear water, rumpons can only be fished successfully during

the short periods of twilight before sunrise and after sunset. In turbid water fishing can be practised in full daylight as well.

Among the many species which gather near the rumpon, the Carangids predominate, layang and deles (round scad, *Decapterus russelli* Rüpp. and *D. macrosoma* Blkr.), and several *Selar* species (scad). Next in economic importance are the Clupeid lemuru (*Clupea leiogaster* C. V.) and the mackerels, kembung perampuan and kembung lelaki (*Scomber neglectus* van Kampen and *S. kanagurta* Cuv.). Also, in turbid water, the bawal hitam (black pomfret, *Stromateus niger* Bloch) is sometimes abundant. In some places (e.g., in West Java) special rumpons for collecting tembang (*Clupea fimbriata* (C. V.)) are provided with "alang-alang" (*Imperata* spec.) or similar coarse grasses instead of palm leaves.

In the aggregate, rumpon fishing in the Java Sea results in annual landings of 40,000 to 50,000 tons (B o t t e m a n n e, 1941, Chapter II.). This production depends wholly on the peculiar habit of the species concerned of hovering in the vicinity of the leaf-lures. It is worth considering what stimuli might be responsible for this effect. In analysing the factors at work, we have to keep the problem well apart from the mechanism of similar concentrating agents, acting under different conditions. In some freshwater lakes, twigs, floating islands, or other herbaceous material are used as rumpons. Especially in stagnant water, these are likely to promote favourable feeding conditions for the fish, and also make a shelter against the glare of the sun.

As regards the reasons for the gathering of the fish near the palm-leaf lures in the sea, several opinions are held. Sometimes it is believed that the fish feed on the leaves, but this assumption is in no way supported by an examination of stomach contents of fish from the rumpon; the organisms which after some time grow over the leaves are not the food of the fish (R e u t e r, 1938). Moreover, the attraction of fresh, clean leaves is practically the same as that of old ones. Although the pomfret might perhaps be exceptional in its behaviour near the rumpon, the following practice seems completely to exclude feeding as the attractive action of the lure. A school at the surface, conspicuous by the ruffling of the water, can sometimes be captured with the help of an emergency rumpon, hastily prepared by tying several pieces of clothing together.

According to others, the fish like to hide in the shadow of the leaves. This idea, however, does not seem to agree with experience. In some experiments, leaves have been replaced by thin sticks extending transversally, made of split bamboo (R e u t e r and v a n P e l, private communication). Moreover, at times the fish can even be collected with a bare rope.

Since sight has been proved to be essential in the schooling of pelagic fish (P a r r, 1927; S p o o n e r, 1931), we cannot completely exclude the possibility of optical orientation. This factor, however, cannot fully explain the action of the lures in the dark or in water of low transparency. If the fish relied on their eyes only, they would fail to

maintain their position, and tend to be carried away by the current. Nevertheless, experience reveals that rumpons do allow successful fishing at sunrise, or in turbid water. Moreover, the schools are said to lie upstream from the rumpons, and the fish stem the current, so that the leaves are for the most part in the fish's blind angle (V e r r i e r, 1927, 1928), which must be definitely unfavourable for taking visual bearings of the lure.

Another pelagic fishery depending on the same principle is practised by the Mandarese (Celebes) in the deep waters of the Gulf of Mandar and the Gulf of Bone (v a n P e l, 1941, p. 14—15). A bamboo raft, composed of 60 to 100 poles tightly lashed together, is moored with a rattan cable in depths of about 1000 metres. At both ends, the cable has a big loop, the upper one going round the raft, the lower one keeping together about 3 tons of stones. The edges of the raft are provided with coco-palm leaves, directed downwards in the water. A bamboo staging is constructed one metre above the raft for resting, storing the gear, etc. Communication with the shore is maintained with sailing prahus. It is surprising how the Mandarese have managed to moor these rafts in the deep sea. Although this fishery has nothing like the economic importance of the rumpon fisheries in the Java Sea, these people have shown considerable ingenuity and skill in developing their own technique with local materials only.

A variety of fish swimming nearby in the clear water at different levels under the raft makes a beautiful scene. Among the species present, we find again the layang, several other Carangids, Clupeids, etc. At sunrise and at sunset a three-pointed draghook is lowered from the raft. As soon as the angler feels something gently butting against the line, he jerks the hook, which pierces the fish. This is used as bait for tuna trolling in the vicinity of the raft. Some fishing is also done with a net known as "djala lompo", resembling a payang. Among the smaller fish conspicuous in lingering near the raft, there is a dark coloured species, the ilah batang (a rudderfish, *Kyphosus waigiensis* A. G.), known for its preference for trees and other floating objects, together with the sunglir (runner, *Elegatis bipinnulatus* (Q. G.)).

During the west monsoon, many trees come down the rivers of Borneo, and enter Macassar Strait. These are profitably fished by the Mandarese with the djala lompo. Layang and ilah batang are well represented in the catches. The ilah batang has a habit of keeping closer to the surface than the layang, so that the natural behaviour of the former can be more easily observed. Probably it is this species which we have seen so many times near logs, coco-nut husks, etc. during a cruise in the north Moluccas. In a calm sea, it was clearly seen that the fish often keep at a distance of one metre or more from the floating body, but hurriedly take refuge under it on the approach of the ship. It seemed to me significant that a stick of no more than two inches in diameter should be able to collect a small school of fish around it, which again shows that the shadow is not the essential factor in the attraction.

Even at sunrise, these fishes were nearly always seen keeping

company with a solitary coco-nut or with any other rigid body afloat. Apparently they had not lost their bearing in the dark, which would hardly have been possible if they had to rely on their eyes alone. Moreover, it was evident that the fish were only attracted to such flotsam as by its movement acted as a wave centre. Tufts of seaweed of the same size are too supple in texture to cause any commotion in the water, and were not seen to be accompanied by fish. It seems as if the periodic disturbances in the water are essential to their orientation.

A number of fish, the majority of which are Carangids (H a r d e n b e r g, private communication), are known to accompany swimming medusae. The rhythmical contractions of the umbrella are likely to emit stimuli similar to those in the case of the bobbing coco-nut. Both examples seem to agree with the view of M a t o u t (1923), who emphasized that perception of pressure variations must play an important part in the fish's life. Perhaps it is not too far-fetched to use the same idea in an attempt to analyse what happens when the fish gather near a rumpon.

The float is composed of a number of parallel bamboo poles tied together, with their basal parts pointing the same way. The rope which is attached to this extremity, facing the waves, transmits its jerky motions downward and shakes the palm leaves under water. Although this might contribute to their attractive effect under normal conditions, it fails to explain certain observations made in a strong current. When the current is strong enough to draw the float so deep under the surface that it is no longer subjected to the motion of the waves, the fish still manage to maintain their position (v a n P e l, private communication). In this case perhaps the stream causes the leaves to rustle and vibrations comparable to aeolian sounds are likely to arise. Although, by exclusion of other explanations, we are inclined to assume the existence of infrasonic perception in the rumpon fish, this reasoning is by no means convincing. Nevertheless, it demonstrates the need of research in the field of low-frequency vibrations.

4. Tuna fisheries.

When surveying the traditional fishing methods in Indonesia, we find that tuna and allied species are mainly hooked, either by trolling or by rod-and-line fishing. Trolling is usually practised from small outrigger canoes, preferably under sail, manned by two or three men, each tending his own gear. Successful trolling is said to depend on the presence of coral reefs and clear water. In the Java Sea conditions are suitable during the west monsoon, especially around the groups of smaller islands and reefs, e.g., the Thousand Islands, the Karimun Djawa Islands, Bawean, and Kangean Islands.

A detailed description of the trolling technique of the Thousand Islands has been given by M a n o u a i n (1941, p. 3—7, 15—17). In his report mention is made of several types of "tonda" or trolling gear, two of which are of interest to our present subject. The first type, the

"pembose" or tonda tongkol, is used for taking tuna species, viz., tongkol (*Euthynnus affinis* Cantor) and abu-abu (*Neothunnus rarus* Blkr.). The other type, the tonda tengiri, is meant for catching tengiri (seer fish, *Cybium spec. div.*). In both types, a tonda consists of a cotton line, a wire leader, a feathered lure, and a barbed hook.

In the first type, the line is 30 to 45 fathoms long, and the leader, 1½ fathoms. The tonda tongkol is not baited, and is fished about one metre under the surface. The lure of the tonda tongkol is made with cock feathers and goat hair; sometimes duck feathers are used instead. A whirl of flexible feathers (of about 6 cm. in length), from the cock's neck, is tied to a tubular piece of bamboo, 4 mm. in length and 3 mm. in diameter. This device is called a "gegewos". For one assembly, two gegewos are made up with feathers, and one with goat hair. This set is threaded on to the wire leader in such a way that the feathers of the whirl nearest to the end point backwards, projecting beyond the hook. The feathers of the other whirl, as well as the goat-hair gegewos which is fixed between the two gegewos, point in the reverse direction.

For taking tongkol, the choice of feathers is by no means arbitrary. Their dominant colours should agree with the general appearance of the bait on which the tongkol is feeding at the time. For instance, on one day the black feathers should predominate among the reddish brown; on others, a bluish or greenish reflection seems to be more attractive. When the fishing is not satisfactory, the stomach contents of the first tongkol taken are examined, and, if necessary, the feathers are replaced by another set of more suitable appearance.

The tongkols feed on the little fish hovering about in the vicinity of the reefs. These bait fish are mainly encountered upstream, and the favourable place for trolling is the so-called "kepala harus" ("head of the stream"), where a prominent corner divides the approaching water masses of the surface current, so that the craft must be sailed over this spot again and again. When tongkols are seen near the surface, one of the fishermen splashes the water with his hands, and at the same time the lines are hauled so as to increase the speed of the lures, thus amplifying the attendant disturbance in the water[1]). This manoeuvre seems to incite the tunas to strike the lure. A shower of rain is said to add to the excitement of the fish, and results in a good catch, whereas turbid water is regarded as unfavourable.

The tonda tengiri (M a n o u a i n, 1941, p. 15—17) has a line of only 4 to 5 fathoms in length and a wire leader of about 30 fathoms; a swivel (made of horn) is mounted between line and leader. Because of the long leader, the hook will fish at a depth of four to eight fathoms. The lure is composed of two feathered gegewos, the foremost directed foreward, the other one covering the hook. In addition, the hook is baited with a small fish. As the tengiri seems to be less particular about colour, very often white feathers are used. Sometimes pieces of

[1]) The optimum speed of a trolling lure is said to be 4½ miles per hour and should not exceed 5 m.p.h.

white and red cloth are used instead, interwoven with strings of twisted human hair. When the tengiri are striking freely, merely a white rag and a bare hook will suffice. Operating conditions and manipulation are the same as in tongkol fishing, and often the two types of gear are tried alternately.

The feathered lures, especially the peculiarities of the colours required, indicate visual attraction. This conclusion is supported by the general opinion that turbid water is unfavourable. This does not mean, however, that no other than optical stimuli affect the fish. The feathers will cause some disturbance in the water, and this must be discernible at a distance especially when a suitable speed has been attained. The belief that success in trolling depends on the speed of the lure through the water suggests that mechanical disturbances are also instrumental in stimulating tunas to attack. Additional excitation of the fish by manual splashing or a rain shower seems to support this view.

In the ancient method of rod-and-line fishing for tuna, angling is performed by a team of 6 to 8 men in a small craft under oars, known as "prahu funai" (W o r a n g, 1948). The gear consists of a bamboo pole, with a hook at the end of a 30 cm. wire leader and 3 m. of line. Attachments are so made that the parts may be rapidly removed and changed. In common practice the barbed hook is baited, but sometimes it is provided with white feathers instead. Fish as live bait are indispensable for attracting and exciting the tunas. This fishery is dependent mainly on two species, primarily the tjakalang (skipjack, *Katsuwonus pelamis* (L.)) and secondarily the smaller madidihan (yellowfin tuna, *Neothunnus macropterus* (Schl.)). These two species have similar oceanic habits, but where the slope of the sea bed is steep enough, they approach the coast and even enter bays, thus coming within reach of the local fishermen. The Bay of Ambon is known for its favourable conditions in this respect.

Early in the morning the boats are paddled to the fishing grounds. The live bait, preferably spratelloids, anchovies, or sardines, are kept alive swimming about in the bottom of the boat, between the feet of the fishermen. A couple of holes in the hull allows water to enter the boat; the holes can be plugged when necessary. The sea-birds, hovering above a school, give appreciable help in locating the fish. Their presence attracts the fishermen's attention to the dark, ruffled spot in the sea, where the tunas are sometimes seen leaping. The school is then approached as speedily as the paddles allow, and when the boat slows down, the crew begin to throw out live bait to attract and excite the tunas; this procedure is called "chumming". The excitement brought about by this chumming is supported by splashing the water with a bamboo scoop. Meanwhile the lines are paid out from the stern until the hooks are about one foot below the surface, and two men at the oars keep the boat moving slowly. When the fish are biting well, a good number of them will be taken in succession with each hook.

The practice is mainly restricted to the eastern part of the archipelago, the best season being during the east monsoon. In the north

Moluccas, the Tidorese have probably specialized for a long time in tuna angling, and every year they travel to their favourite sites in the surrounding region to resume their trade (W o r a n g, 1948). Ambonese and Bandanese have adopted the same method. The Tidorese word "funai" strongly resembles the Japanese word "fune", which means boat. This reveals early relations with northern peoples, but is not to be connected, however, with the recent invasion of Japanese fishermen (from 1929 up to world-war II). Their technique was based on the same principles of chumming and angling, but was adapted to modern mass production.

The outstanding features of their equipment are as follows (S h a p i r o, 1948). The boats are powered. On the daily trips, the fish to be used as bait ar kept alive in special wells in the hull. The rods are used mainly on the port side, from a special platform extending from the bow, fishing over the stern being less common. A sprinkler system under the platform replaces the splashing of the water by hand.

Rod and line are about equal in length. Line and wire leader are separated by a swivel, and have a total length of about 1½ m. Attachments are such as to allow easy renewal of parts. Two types of hooks are used. One consists of a plain galvanized, barbless hook with a short shank. It is baited with a small live fish. The other type is similar, but the shank is embedded in an oblong piece of lead, or (in the larger sizes) in a piece of brass tube filled with lead. White feathers are attached to the lead, and project beyond the hook. This is known as a striker. When in use, the point of the hook is directed upwards. The under side of the lead is sometimes adorned with glittering, red and green celluloid rectangles. The absence of a barb makes it possible to unhook the fish readily. This is important, since quick action is required to get as many fish on board as possible before a school is lost. Fishing with live bait on the hook is slower than the striker method. In consequence, baited hooks are only used when the strikers fail.

We learn from experience that the fish thrown out as live bait immediately attract the tunas, even at a distance of 35 m. or more. Although attraction by taste may be important in long-lining for tuna, this cannot be the directing stimulus here, because of the immediate reaction at a considerable distance. Visual attraction must also be excluded in the inital phase of attack. In the first place it seems doubtful whether the tuna's eyes could give a clear image of a couple of tiny fish at such a distance. Moreover, in a rough sea, when tuna and prey happen to be close under the surface in different wave crests, the troughs between conceal the prey from its predator. Yet in these circumstances chumming proves successful. Thus we are led to the assumption that the tuna's reaction to live bait at considerable distances is due to mechanical stimuli, perhaps sonic. This reminds us of the results of W u n d e r (1927), who studied attack release in a blind pike (*Esox lucius* L.). A similar reaction has been found in sharks (W r i g h t, 1948). At times chumming is applied when a shoal is being pursued (M a c k e n z i e, private communication). Since, in this situation, the

stimulus originates from a source in the tuna's blind angle (V e r r i e r, 1927, 1928), the practice seems to support the previous assumption.

Chumming with dead fish has no effect at a distance, but when thrown out quite near the tunas, the motionless bait is immediately attacked and swallowed (H. v a n P e l, private communication). It is likely that sight becomes more important as the tuna approaches its prey and is about to strike. The common use of the white-feathered lures with conspicuous pieces of red and green celluloid would seem to support this view. Splashing and sprinkling water around the hooks helps to excite the tunas and makes them strike at the hooks.

Thus it seems that in both phases of attack, mechanical (or sonic) stimuli seem to be largely responsible for the tuna's behaviour, which results in its capture. Therefore a thorough study of the disturbances emitted by small fish and by the sprinkling of water is needed to arrive at a closer understanding of some of the devices used by the local fishermen.

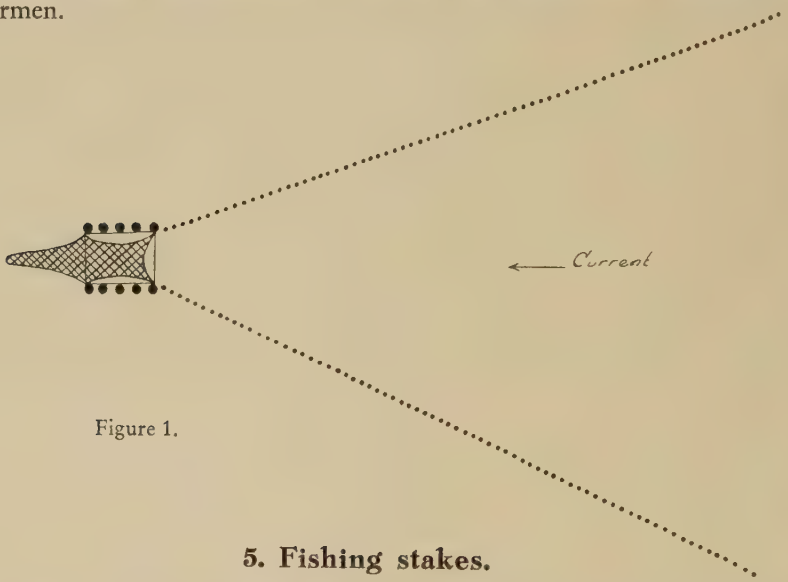


Figure 1.

5. Fishing stakes.

In shallow coastal waters, we find several kinds of palisades and enclosures, erected for the purpose of trapping fish or shrimps. There is considerable diversity in form and construction of these fishing stakes. Some of them are especially suited to a region with great differences in tidal levels, and are designed for fencing off a part of the sea at high tide, and enabling the fisherman to pick the fish from the mud at low water. This procedure depends little on the actions of the fish and has not much to do with the fishermen's understanding of fish behaviour. In this respect we find more interesting inventions in those structures with one or more wings or leads, which jut out for a considerable distance, causing the fish to move towards some enclosure, and thus functioning as a trap.

Where strong tidal currents predominate, as is the case in the estuaries of the larger rivers entering the Straits of Malacca, the essential features of the construction consist of two great wings arranged in a V-shape. The open side of the structure is directed towards the current, so as to lead the fish into an enclosure. In most localities, the ebb current is of the more suitable strength for this practice.

The main fishery at Bagan Si Api Api (Rokan region, east coast of Sumatra) depends on the use of an extensive two-winged type (Figure 1), the so-called "jeremal" (S t e a d, 1923; M a r k u s, 1929). Each wing of this structure consists of a long row of palm stems, forced into the mud. The spaces between the stems are not filled in, and the openings are quite wide enough for fish to pass through if they so wished. The fish, however, seem afraid to pass between the stakes, and as the strength of the current prevents them from swimming against it, they are driven into the trapping enclosure.

It is worth considering what stimuli are instrumental in this behaviour. It cannot be denied that most fish are able to see an obstacle in clear water by day, especially at close quarters, but these conditions do not seem to be fulfilled in the present case. Occasionally, screenless jeremal wings work in extremely turbid water of 5 fathoms depth, and therefore it is not likely that visual impressions play an important part.

As the palm stems are not connected together, they are free to sway separately in the strong current according to their own natural period. The excitation of the fish has been ascribed to this swinging motion of the stems (S t e a d, 1923, p. 224). This disturbance will of course be most violent at the surface, but weak or even absent near the bottom. So if this were the only stimulus affecting the fish, the wing would not work near the bottom, and it seems reasonable to consider another source of disturbance in the water.

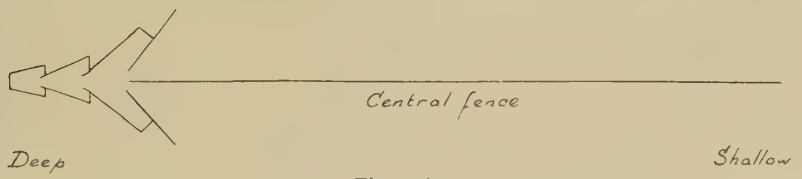


Figure 2.

Whenever the water passes between the stems at a speed of 5 knots (as is the case in the Rokan estuary), a regular succession of small whirlpools is formed just behind the stems. These swirls form alternately on each side, those on one side spinning one way, those on the other side the opposite way. The flow past the obstacle wavers from side to side and the period of oscillation depends on the speed of the current and the diameter of the stakes[1]). These "aeolian" vibrations might reach

[1]) In the mouth of the Belawan river, where the outgoing tidal current hardly reaches 2 miles per hour, similar V-shaped structures are erected, but these consist of thin sticks, connected with crossbars.

the range audible to the fish (either by the ear or the lateral line) so as to become a sonic signal.

Another type of construction, the "sero" or "belat", which is plentiful in some coastal waters, consists of a single screen-covered wing or fence, extending towards the beach (Amirroedin, 1949; van Kampen, 1906, 1909, 1922). At the seaward extremity, there is a series of three or four compartments of diminishing size, the last one, called the "bunuhan" or "death chamber", being the smallest (Figure 2). The main fence intercepts fish travelling along the shore in either direction. Since the fish tend to swim against the current, interception is aided by the tidal currents along the coast.

The screen seems in some way to frighten the fish, and when they encounter it, they try to make for deeper water, as scared fish usually do; accordingly the main fence need not be extended right up to the beach. At the other end, the fence terminates in the centre of the entrance to the first compartment. Sometimes the wings of this compartment are lengthened by extensions on both sides, to help to lead stray fish back to the opening in the centre of the structure. These wings are concave towards the direction of approach to the compartment, so that the fish find it easy to enter, but hard to go back. Their attempts to escape finally lead them, by similar passages, to the "bunuhan".

The crucial point of this technique lies in the fear the fish experience on encountering the screen, and it is a remarkable fact that the contrivance will not work satisfactorily when the bamboo screens become overgrown with barnacles[1]). The whole structure is therefore taken down, scraped clean, and rebuilt every month, usually in the same place. Although, in the present state of our knowledge, it seems difficult to know what stimuli are effective in frightening the fish, it is worth mentioning that the sero is said to work best during dark nights with no moon (unless phosphorescent organisms are present). Moreover, for daytime fishing, the water should not be too clear.

Apart from the fact that the fish are frightened by the screen, their behaviour when they rush back to deeper water confronts us with a most puzzling problem, How do they know the right direction to take? There are several other related problems. How can the layang in the Java Sea manage to avoid water of less than 35 m. depth? Why do healthy fish never get stranded, even on dark nights and in turbid water?[2]) By what kind of stimuli can a fish appreciate depth conditions in its environment? At times the shore exerts a considerable influence on temperature, transparency, and chemical composition of the water. These factors may eventually affect the fish, but even taken together, they fail to explain why the general trend of swimming is such that the fish does not strand; this seems to be so natural that it has hardly ever been questioned.

[1]) Live barnacles are reported to be soniferous, giving clicks of low intensity (Knudsen *et al.*, 1948, p. 420).

[2]) The sunfish (*Orthagoriscus mola* (L.)), the saury pike (*Scomberesox saurus* (Walb.)), and the Ray's bream (*Brama raii* (Bloch)) are remarkable exceptions. These oceanic fish are frequently reported as having stranded alive.

One might think it possible for a fish to get a visual impression of the inclination of the bottom. Although this could not explain navigation in the dark, or in turbid water, it is interesting to note that T a u t i and Y a s u d a (1933) have undertaken some experiments with seem to bear on this possibility. A part of an aquarium was divided into two compartments with a net, placed perpendicular to the lines of equal depth. The direction in which a fish group moved, after having been obstructed by the net, was studied for different inclinations of the bottom. When the bottom was inclined at an angle of 25°, nearly all the fish groups swam to the deeper side. At angles of 5—10°, the inclination appeared to have no influence. This seems to suggest that visual impressions might in certain cases be of help to a fish in navigation, but it must be recalled that along shallow shores sight can be of little help, even in daytime.

Again, by a process of elimination, we finally arrive at the only remaining assumption, viz., acoustical stimuli. From a survey by K n u d s e n *et al.* (1948) it appears that the ambient noise in the sea largely depends on the state of the surface, and extends over a considerable range of frequencies. A ruffled water surface (as the sea practically always has) emits sound vibrations in a downward direction, which resound from the bottom. This results in resonance with an average wave-length of four times the depth. Thus a certain resonance frequency maximum is typical of a certain depth[1]). Lateral deviation of these low-frequency vibrations enables an impression to be obtained of surrounding depths. The frequencies required for navigation by the fish are likely to belong, for the greater part, to the range which is infrasonic to the human ear, and these vibrations have so far attracted only little attention (if any) in marine acoustical research.

However acceptable this view may seem, it is clearly desirable to have special studies of low-frequency vibrations in coastal waters, and to make experiments on the sensitivity of the fish to these vibrations. In this respect it is interesting to find that the optic as well as the acoustic brain centres are well developed in pelagic teleosts (E v a n s, 1940)[2]).

6. Conclusion.

From experience in several fisheries it seems likely that in orientation and in communication, fish rely greatly on sound. Although no experimental proof has been given, indirect reasoning leads to the assumption that fish are affected by low-frequency vibrations.

[1]) Although no scientific observations of this phenomenon are yet available it is interesting to note the observations of people skating on ice when the condition of the surface is suitable for the transference of vibrations to the water below. Such skaters are able to estimate the depth of the water below them by the pitch of the sound made by their skates on the ice (Prof. M. G. M i n n a e r t, Utrecht, private communication).

[2]) In the sunfish, however, the optic centres are the only sensory brain parts suggesting an important function in the fish's life (B u r r, 1928). A detailed study of the brain of the saury pike and of Ray's bream does not seem to be available yet.

Vision has been proved to be instrumental in attack release in predators, and in schooling behaviour of pelagic fish, but only at close quarters. The fish's vision of comparatively small objects is blurred, because the dioptrics of their eyes are imperfect. Sonic stimulants, however, are clearly perceived at relatively great distances. Hence acoustical research seems to be the more promising line to follow in the development of technical imitations of natural stimuli. This might sooner or later lead to improvement in fishing methods.

References.

a. General.

Burr, H. S., 1928. "The central nervous system of *Orthagoriscus mola*". Journ. Comp. Neurol., **45**, No. 1, pp. 33—128.

Evans, H. Muir, 1940. "Brain and body of fish". The Technical Press Ltd., London. 8°, 164 pp.

Frisch, K. von, 1936. "Über den Gehörsinn der Fische". Biol. Reviews, **11**, No. 2, pp. 210—246. Cambridge.

Knudsen, V. O., R. S. Alford, and J. W. Emling, 1948. "Underwater ambient noise". Journ. Mar. Research, **7**, No. 3, pp. 410—429. New Haven, Conn.

Matout, L., 1923. "La pêche et les sens des poissons". Rev. Hist. nat. appl., 1re Part., **4**, No. 10, pp. 298—307; No. 11, pp. 321—328.

Parker, G. H., 1918. "A critical survey of the sense of hearing in fishes". Proc. Amer. Phil. Soc., **57**, No. 2, pp. 69—98. Philadelphia.

Parr, A. E., 1927. "A contribution to the theoretical analysis of the schooling behaviour of fishes". Occasional Papers, Bingham Oceanogr. Coll., No. 1, pp. 1—32. New Haven, Conn.

Piper, H., 1906. "Aktionsströme vom Gehörorgane der Fische bei Schallreizung". Zentralbl. f. Physiol., **20**, pp. 293—297. Wien.

Piper, H., 1906. "Über das Hörvermögen der Fische". Münchener mediz. Wochenschr., **53**, p. 1785.

Spooner, G. M., 1931. "Some observations on schooling in fish". Journ. Mar. Biol. Assoc., **17**, No. 2, pp. 421—448.

Tauti, M., and H. Yasuda, 1933. "The direction in which a fish group goes after having met with a net". (In Japanese with English summary). Bull. Japanese Soc. Sci. Fisheries, **2**, No. 1, pp. 17—19. Tokyo.

Verrier, M.-L., 1927. "Sur la détermination du champ visuel anatomique chez les poissons et les batraciens". Comp. Rend. Hebd., Acad. Sci., **184**, No. 24, pp. 1482—1484. Paris.

Verrier, M.-L., 1927. "Détermination de l'étendue des champs de vision anatomique chez quelques téléostéens". Bull. Soc. Zool. France, **52**, p. 329. Paris.

Verrier, M.-L., 1928. "Recherches sur les yeux et la vision des poissons". Bull. Biol. France et Belgique, Suppl. 11, 222 pp. + 12 pls. Paris.

Wright, B. S., 1948. "Releasers of attack behaviour pattern in shark and barracuda". Journ. Wildlife Management, U. S. A., **12**, No. 2, p. 117—123.

Wunder, W., 1927. "Sinnesphysiologische Untersuchungen über die Nahrungsaufnahme bei verschiedenen Knochenfischarten". Zeitschr. vergl. Physiol., **6**, No. 1, pp. 67—98. Berlin.

b. Regional.

Amirroedin, 1949. "De sero en de tegur in de Baai van Batavia". Korte Meded. Dienst Zeevisscherij, No. 2, 24 pp. Batavia

Bottemanne, C. J., 1941. "Verslag van de werkzaamheden over 1940". Meded. onderafd. Zeevisscherij (Dept. Econ. Zaken), No. 7, 70 pp. Batavia.

Brink, J. F. E. ten, 1910. "De lajangvangst". Tijdschr. v. h. Binnenlandsch Bestuur, **39**, No. 1, pp. 28—35. Batavia.

Djoemhana, M., 1941. "Zeevisscherij-verslag van Str. Tioro". Inst. v. d. Zeevisscherij. Mimeogr. 66 pp. + 2 fld. pls. Batavia.

Domantay, J. S., 1940. "Tuna fishing in southern Mindanao". Philippine Journ. Sci., **73**, No. 4, pp. 423—436 + pls. 1—9. Manila.
Firth, R., 1943. "The coastal people of Kelantan and Trengganu, Malaya". Geogr. Journ., **101**, Part I, No. 5/6, pp. 193—205 + 4 pls. London.
Hardenberg, J. D. F., 1931/34. "The fish fauna of the Rokan Mouth". Treubia, **13**, No. 1, pp. 81—168 + 1 fld. chart (1931); **14**, No. 3, pp. 299—312 (1934). Buitenzorg.
Hasselt, A. L. van, and H. J. E. F. Schwartz, 1898. "De Poelau Toedjoeh in het Zuidelijk gedeelte der Chineesche Zee". Tijdschr. Kon. Nederl. Aardr. Genootsch., Ser. 2, **15**, pp. 21—45 + chart II; pp. 154—199 + 4 pls.; pp. 444—476 + 4 pls.; pp. 657—692 + 7 pls. + 1 chart. Amsterdam.
Kampen, P. N. van, 1906. "Overzicht der hulpmiddelen bij de zeevisscherij van Java en Madoera in gebruik". Meded. v. h. Visscherij-Station, No. 1, pp. 1—32. Batavia.
Kampen, P. N. van, 1909. "De hulpmiddelen der zeevisscherij op Java en Madoera in gebruik". Meded. uitg. v. h. Dept. v. Landbouw, No. 9, 116 pp. + 19 pls. Buitenzorg.
Kampen, P. N. van, 1922. "Visscherij en vischteelt in Nederlandsch-Indië". Onze Koloniale Dierenteelt, No. 2, sm. 8°, VI+106 pp. Tjeenk Willink & Zoon, Haarlem.
Manouain, J. E., 1941. "Onderzoek der zeevisscherij van de Duizendeilanden". Inst. v. d. Zeevisscherij. Mimeographed, 87 pp. Batavia.
Mare, D. W. le, 1946. "Annual report of the Fisheries Department, Malayan Union and Singapore, for the year 1946". Mimeographed, 40 pp. Singapore.
Markus, B., 1941. "Visscherij-methoden en vischproducten van Bagan Si Api Api (Mei 1929)". Inst. v. d. Zeevisscherij. Mimeographed, 35 pp. Batavia.
Pieters, D., 1923. "Een luidruchtige visch". Tropische Natuur, **22**, No. 3, pp. 39—43. Batavia.
Pel, H. van, 1938. "De beoefening der majang zeevisscherij langs de Noordkust van Java". Meded. v. h. Inst. v. d. Zeevisscherij, No. 2, pp. 101—113. Batavia.
Pel, H. van, 1941. "Mededeeling van het Instituut voor de Zeevisscherij, Station Makassar, over 1940". Inst. v. d. Zeevisscherij. Mimeographed, 50 pp. Batavia.
Pranjoto, R., 1939. "Jaarverslag over 1938 van de visschersvereeniging 'Misojo Sari' te Tandjoengsari (Pemalang)". Jaarverslagen Visschersorganisaties over 1938. Inst. v. d. Zeevisscherij, Verslag No. VII (Pemalang). Mimeographed, 31 pp. Batavia.
Reuter, J., 1938. "Voorloopige mededeeling omtrent het 'roempon'-onderzoek". Meded. v. h. Inst. v. d. Zeevisscherij, No. 2, pp. 132—136. Batavia.
Roosendaal, A. M. van, 1910. "De lajang-visscherij in de Java-zee en in Straat Madoera". Meded. v. h. Visscherij-Station, No. 5, pp. 21—41 + 1 chart. Batavia.
Shapiro, S., 1948. "The Japanese tuna fisheries". Gen. Headqu. Supr. Cdr. Alld. Pow. Natural Resources Section, Rep. No. 104, 60 pp. Tokyo. Reprod. 1948: U. S. Dept. Int., Fish and Wildlife Service, Fishery Leaflet No. 297. Washington D. C.
Stead, D. G., 1923. "General report upon the fisheries of British Malaya with recommendations for future development". Issued by authority of the Colonial Secretary, Straits Settlements, and of the Chief Secretary, Federated Malay States. 8°, 372 pp. + 19 pls. Sydney, N. S. W.
Worang, L. K., 1948. "Verslag over de visscherij van de Tidoreezen op Naimoedoeng". Bijlage Maandverslag, Visscherijstation Aer Tembaga over October 1948" F°, 6 pp.

Salmon of the River Shannon (1948-1951).

By

Arthur E. J. Went,

Department of Agriculture, Fisheries Branch, Dublin.

Introduction.

In a paper published in 1950 ("Salmon of the River Shannon in 1946 and 1947", *Journ. du Cons.*, **16**, No. 3) the writer described the continuous investigations which were being carried out on the salmon stocks of the River Shannon in an effort to follow the annual changes in that river. During the period 1948 to 1951, inclusive, further material was collected on the same lines as previously (see W e n t, 1950, p. 341). This consisted of representative sets of scales and data from salmon taken by the fishing weir at Limerick known locally as "Thomond Weir". All the fish entering the weir are counted (see W e n t, 1943) and a proportion (only 28 % at present) are retained for marketing. The four additional years now described give us a long series of observations which are worthy of being placed on record. No account is taken of the fish captured seawards of Thomond Weir, as the intensity of the fishing in that region has remained more or less constant since 1941.

Runs of Fish.

The estimated numbers of fish entering Thomond Weir in 10-day periods from 1948 to 1951 are given in Table 1. These figures differ slightly from the actual returns because allowances have been made for short periods when the weir was out of operation for various reasons. Estimated figures for 1941 to 1947 were included in W e n t, 1950 (Table 16, p. 353), and the results for 1941 to 1951 inclusive are illustrated in Figure 1. There was a steady decrease in the runs of fish from 1941 to 1945 which was followed by a rise in 1946, a fall again in 1947, followed by a rise until 1950 and a slight fall in 1951.

Fish entering the weir until 20. May are, in the main, spring fish and thereafter the bulk are summer fish. If, therefore, we divide the season into two parts, namely, up to 20. May and from 21. May to the end of the season, we can obtain some idea of the relative abundance of the two types of salmon (see Table 2 and Figure 2). In the case of both types of

Table 1. Estimated runs of fish based on the returns to Thomond Weir.

	1948	1949	1950	1951
Jan. 1 — Feb. 10	36	130	91	52
Feb. 11 — 20	72	233	91	52
Feb. 21 — end of month	99	218	63	49
March 1 — 10	181	225	199	200
„ 11 — 20	343	248	322	163
„ 21 — 31	258	319	242	137
April 1 — 10	308	577	866	277
„ 11 — 20	448	371	400	561
„ 21 — 30	305	512	494	602
May 1 — 10	505	258	93	441
„ 11 — 20	147	372	337	480
„ 21 — 31	215	630	555	847
June 1 — 10	1,550	1,948	1,054	933
„ 11 — 20	1,537	2,542	2,977	2,547
„ 21 — 30	2,629	2,602	3,693	2,762
July 1 — 10	912	1,799	2,275	3,128
„ 11 — 19	336	298	1,182	903
Total	9,881	13,282	14,934	14,134

fish there was a minimum in 1945 (this year was probably the worst for over 50 years as regards the runs of salmon into Irish rivers), although the 1947 runs of spring fish were probably of the same order as those of 1945. The year 1947 was, however, abnormal from the point of view of the weather, especially for the first four months and it seems likely that there may have been some delay in the time of running of the spring fish.

The proportion of summer fish varied from 72·7 % in 1948 to 89·8 % in 1941, which was pre-eminently a summer-fish year. These figures clearly show, as explained in a previous paper (Went, 1946), that the Shannon is now mainly a summer-fish river unlike its previous (pre-hydro-electric) character, when the bulk of the runs were of spring-fish.

Table 2. Number and proportion of fish running up to and including 20. May and thereafter.

	Number up to 20. May	% of 1941 number	Number after 20. May	% of 1941 number
1941	2,299	100	19,704	100
1942	3,134	136	15,191	77
1943	3,052	133	15,394	78
1944	2,482	108	8,458	48
1945	1,376	60	5,234	27
1946	1,618	70	9,120	46
1947	1,382	60	7,004	36
1948	2,702	118	7,179	37
1949	3,463	151	9,819	50
1950	3,198	139	11,736	60
1951	3,014	131	11,120	56

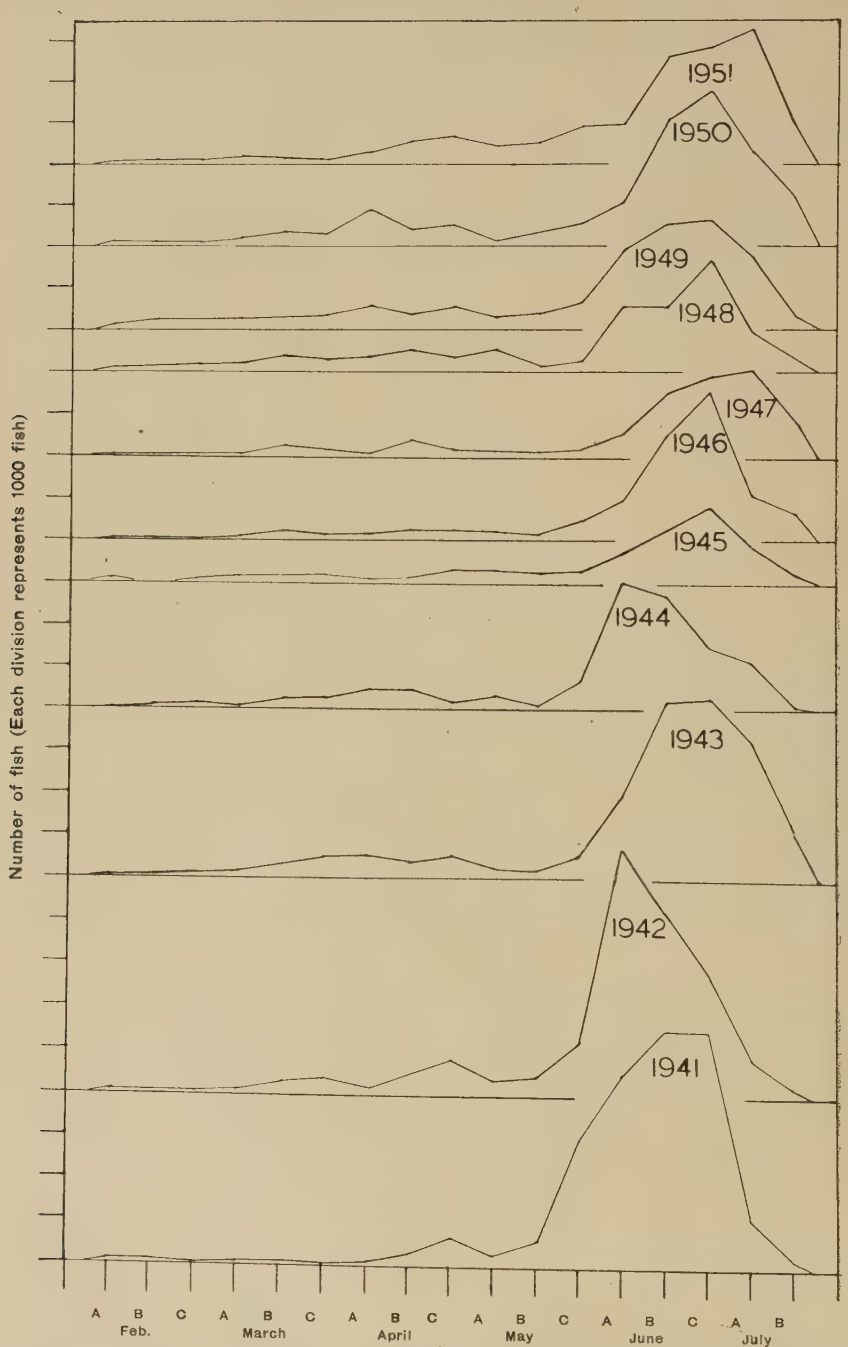


Figure 1. Numbers of fish entering Thomond Weir in 10-day periods throughout the season (A = 1st to 10th inclusive, B = 11th to 20th inclusive, and C = 21st to end of month).

Analysis of the Stocks by Scale Reading.

Each set of scales was cleaned and mounted for microscopical examination. The numbers of sets of scales examined for each of the years from 1948 to 1951, inclusive, were as follows:—

Year	1948	1949	1950	1951	Total
Number of sets of scales examined	1178	1154	1102	991	4425

The age-group and smolt age were noted in each case and as the proportion of the fish sampled month by month varied, the results were suitably adjusted to make allowance for this difference. The samples were representative and adequate for all parts of the season and results may therefore be assumed to be reasonably reliable.

Table 3. Percentage of each smolt class in the different years (maiden fish only).

Salmon runs of	Smolt Class 1	2	3
1948	20·0	77·1	2·9
1949	20·2	76·8	3·0
1950	18·7	79·8	1·5
1951	20·0	77·5	2·5

The proportion of each smolt age has been indicated in Table 3. There was remarkable similarity in the results and the differences between the various smolt classes were less than for any four successive years recorded from the Shannon so far. The fact that the 1-year smolts have been more important than the 3-year smolts has, with one exception, held in every year since these investigations started in 1928. In 1944 the 3-year smolts held a slight advantage over the 1-year smolts.

The distribution of the fish of the different years into the various age-groups has been indicated in Table 4. The present results are of the same order as those of previous years from 1941 onwards; that is to say, the grilse (1 + winters) formed approximately 70 % of the total run with the small spring-fish (2 winters) second in importance but never reaching one-quarter of the total run.

Grilse first commence to run in May and reach a peak in June, corresponding with the peak in the curves in Figure 1. They decrease rapidly towards the end of the season. The small spring-fish (2 winters), on the other hand, reach a peak in April and have virtually disappeared by the beginning of June. May usually sees the peak of the

Table 4. Percentage of each age-group in the different years.

	Age-group in winters						
Year	1+	2	2+	3	3+	4	With SMs.
1948	71·5	23·2	1·6	1·4	—	—	2·3
1949	69·8	24·1	2·5	1·7	—	0·2	1·7
1950	74·1	18·1	4·1	1·1	—	0·2	2·4
1951	72·1	17·2	5·6	1·8	0·1	—	3·2

runs in the small summer-fish (2+ winters). The large spring-fish tend to have reached a maximum before the end of March, although in 1951 more ran in April than in the two previous months combined. Previous spawners vary in proportion considerably from year to year and during the years under review were comparatively scarce.

Previous mention has been made of the fact that the runs of fish up to 20. May each year consist mainly of spring-fish and thereafter they

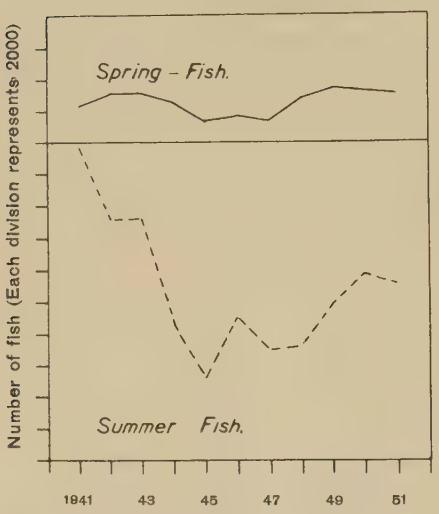


Figure 2. Numbers of "spring" and "summer" fish running in the years 1941 to 1951, inclusive.

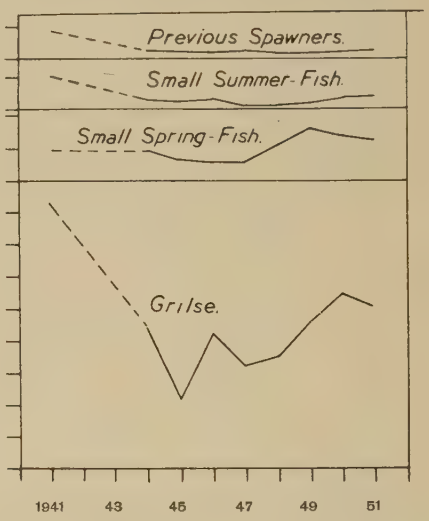


Figure 3. Fluctuations in the numbers of the four most important age-groups in the year 1941, and 1944 to 1951, inclusive. (No returns available from 1941 to 1945).

consist of summer-fish. This is a useful method of estimating the intensity of the runs of the two types of fish for most purposes. In Table 5 the actual numbers of fish running before 21. May and from

Table 5. Comparison of results of dividing fish into "spring-fish" and "summer-fish" on basis of time of running on a scale examination.

	1944	1945	1946	1947	1948	1949	1950	1951
Number of fish running up to 20. May	2,482	1,376	1,618	1,382	2,702	3,463	3,198	3,014
Calculated Number of Spring-fish	2,110	1,420	1,330	1,310	2,430	3,460	2,890	2,690
Number of fish running after 20. May	9,458	5,234	9,120	7,004	7,179	9,819	11,736	11,120
Calculated Number of Summer-fish	9,420	4,810	9,090	6,660	7,220	9,590	11,680	10,990

Table 6. Number of fish in the different age-groups (to the nearest 10) for each year.

Age-Group	1941	1944	1945	1946	1947	1948	1949	1950	1951
1*)	16,510	8,860	4,350	8,500	6,470	7,060	9,260	11,020	10,190
2	1,980	1,860	1,280	1,150	1,150	2,290	3,200	2,700	2,430
2*)	2,110	550	460	590	180	160	330	610	790
3	150	250	140	180	130	140	230	160	260
3*)	—	10	—	*)	10	—	—	—	10
4	20	—	—	*)	30	—	30	30	—
With SMs.	1,230	410	380	310	420	230	230	360	450
Total	22,000	11,940	6,610	10,740	8,390	9,880	13,280	14,930	14,130

*) less than 10 fish.

21. May up to the end of the season have been compared for each year from 1944 to 1951 inclusive with the actual calculated numbers of maiden spring and summer-fish. There is fairly close agreement between the two sets of figures with a tendency for the calculated figures to be smaller than the numbers obtained on the basis of the time of running. This, of course, is only to be expected when we realize that the previous spawners have been ignored in these calculations. There is a tendency to overestimate the proportion of spring-fish by about 10 % but in view of its simplicity, the method is useful for checking the position before one has a chance of reading the scales.

From the actual numbers of fish running during the season in any one year and the scale analysis one can calculate the actual numbers of each age-group in the stocks of any one year. (These calculations have been given for the year 1941 and 1944 to 1947 inclusive in W e n t, 1950, p. 355). Similar calculations were made for the four years under review and they have been given in Table 6. For convenience the previous figures have been given also. The whole range of calculations has

Table 7. Estimated numbers of the different brood years in the catches of the different years.

Brood Year	1944	1945	1946	1947	1948	1949	1950	1951	Remarks and Total of brood
1939	260	10	—	—	—	—	—	—	Incomplete
1940	3,500	200	10	—	—	—	—	—	Incomplete
1941	7,220	1,600	180	30	—	—	—	—	Nearly complete (9,030)
1942	550	3,980	1,700	160	—	—	—	—	6,390
1943	—	440	7,570	1,740	200	10	—	—	9,960
1944	—	—	970	5,020	1,890	210	—	—	7,290
1945	—	—	—	1,020	6,350	2,780	180	—	10,330
1946	—	—	—	—	1,210	8,630	2,390	190	12,420
1947	—	—	—	—	—	1,420	10,480	2,700	Virtually complete (14,600)
1948	—	—	—	—	—	—	1,520	9,050	Incomplete
1949	—	—	—	—	—	—	—	1,740	Incomplete
Total	11,530	6,230	10,430	7,970	9,650	13,050	14,570	13,680	

been illustrated in Figure 3. These calculations show in a clearer fashion the fluctuations in the runs of fish into the Shannon than the variations in proportion from year to year. For example, the proportion of fish other than grilse in 1945 was greater than in any year since 1941. This was not because the actual numbers of small spring, small summer, and large spring-fish were large, but because the numbers of grilse were the lowest on record.

From the information now available we can estimate the numbers of the brood of each year which enter into the stocks. This has been done in Table 7, the previous spawners being omitted. As the calculations only started in the year 1944, it is only from 1942 onwards that the returns are complete. Complete information relating to 5 brood years (1942 to 1946 respectively) is now available and the figures for 1947 are virtually complete, only the numbers of large spring and large summer-fish and very large spring-fish need to be added. As they never amount to more than about 200 fish we may take the number of the 1947 brood reaching maturity as approximately 14,600 to 15,000 fish. In addition, the brood of 1941, the figures for which are also incomplete, probably amounted to about 10,000 fish.

Summary.

1. Collections of scales and data from salmon of the River Shannon were analysed and the variations in the runs of fish were indicated (Tables 1 and 2 and Figures 1 and 2).
2. Approximately 20 % of the total run belonged to the 1-year smolt class, the 3-year smolt class not exceeding 3 % of the total. The bulk were, therefore, 2-year smolts (Table 3).
3. The grilse comprised from 69·8 % to 74·1 % of the total run; the small spring-fish were next in importance from 17·2 to 24·1 % of the total (Table 4).
4. The numbers of spring and summer-fish in each year's catch were calculated and compared with the numbers obtained by consideration of the time of running (Table 5).
5. The numbers of each age-group in each year's catch were calculated (Table 6 and Figure 3). The numbers of fish derived from the brood of different years were given in Table 7. The brood of different years apparently vary in numbers from roughly 6,000 to 15,000 fish.

References.

Went, Arthur E. J., 1946. "Salmon of the River Shannon in 1944 and 1945." Journ. Animal Ecol., **15**, No. 2, pp. 155—169.
— 1950. "Salmon of the River Shannon in 1946 and 1947." Journ. du Cons., **16**, No. 3. Copenhagen.

The Efficiency of Fishing Methods Employed in the Capture of Lobsters and Crabs.

By

H. J. Thomas.

Introduction.

The quantitative determination of fluctuations in the lobster and crab stocks of any area and the evaluation of the population on the grounds are both dependent on the estimation of catch per unit fishing effort. Around the Scottish coast the creel is the gear most generally employed in the commercial fishery for lobsters and crabs. Evaluation of the fishing equation (R u s s e l l, 1931), for these species, is intimately dependent, among other things, on the efficiency of this gear and its varying usages in different areas.

In any one area, on the justified assumption that fishing gear and methods remain fairly constant from one season to the next, comparisons can be made from year to year. R u s s e l l (1931), in formulating the fishing equation, assumes that individuals above a certain minimum length, taken by the gear, are equally catchable. However it may be in other fish, in the case of lobsters another factor will arise since giant individuals will be excluded by the dimensions of the eye of the ordinary type creel (H e r r i c k, 1896). In assessing annual mortality it is essential to know how far the estimate of survivors is materially diminished by a lower efficiency of the sampling gear.

Minor modifications of the basic type of creel are in use around the Scottish coast (Scottish Home Department, 1952) whilst wide differences occur in the baits commonly in use. In making comparisons between one area and another it is necessary to evaluate the relative fishing efficiencies of the types of gear employed and the differences due to the bait which also materially affect the uniformity of the measure of the fishing effort (creel-hauls).

The present investigation into the efficiency of various types of lobster and crab fishing gear, and of certain baits, was undertaken in

the light of the above factors. The work was carried out at the Marine Laboratory of the Scottish Home Department in Aberdeen during 1949. Thanks are due to Mr. J. A. Pope who is the main author of the appendix to this paper, and to Mr. R. Jones for their kind assistance in the statistical treatment of the results, and in addition, to Mr. C. J. M. Cadzow of the Scottish Agricultural Organization Society for the facilities provided in carrying out experiments at their lobster ponds.

II. Material and Methods.

During September 1949, experiments were carried out at the lobster storage pond, operated by the Crofter Supply Agency, at Bernera, Isle of Lewis. This pond consists of a small natural sea loch closed off from the sea by a dry stone wall. Lobsters, which have been fished from the sea by creels during the summer, are transferred to the pond for storage and later refished for sale in the winter markets.

A comparison was made of the length distributions of lobsters caught by the two types of gear normally used in refishing the ponds, viz., creels and scoops. The creel employed was of the single-eyed type typical of the Scottish west coast fishery and described in "Practical Hints for Lobster Fishermen" (Scottish Home Department, 1952). The creels were baited with salted mackerel, usually a half-fish, and hauling was carried out every $1^1/_2$ hours. The scoop (Figure 1) consists of a circular iron ring of 4 feet diameter on which netting is loosely stretched to form a disk. Bait is secured at the centre of the disk by a double twine running above the netting. Four ropes, secured around the circumference, run to a single rope used in manipulation of the scoop. Scoops, baited with a salted mackerel, were lowered on to the bottom of the pond and hauled after about 15 minutes. The majority of lobsters attracted on to the disk remain on the netting during hauling. Scoops were used in this way for commercial lobster fishing prior to the introduction of the creel but are not now much employed except under artificial conditions in refishing from storage ponds. No attempt has been made to compare the fishing effort involved in the use of these two traps, since their relative efficiency is closely related to the concentration of lobsters. In dense populations the scoop is more efficient than the creel and the difference is accentuated with increasing concentration. In the following experiments at the ponds lobsters caught by both creel and scoop were measured to the nearest $^1/_4$ inch.

During the summer of 1949 the Scottish Home Department Fishery Research Vessel "Kathleen" undertook creel fishing, around the Scottish coast, in depths down to 15 fathoms. The creels employed were obtained from a fisherman from the south-east of Scotland. The basic type was the double open-eyed creel of the pattern used in this area (Figure 2). The creel dimensions are given in Table I.

Three modifications were made to this basic type of creel, referred to in this paper as the *standard* creel, thus providing the four creel types used in the experiments. In one modification the lower halves of

both eye-inlets were lined by netting of 17 mm. (0·3″ open square) mesh. This type of creel is referred to as the *fine-mesh* inlet creel. The second modification consisted of braiding over one eye of the standard double-eyed creel converting it into a *single* open-eyed creel. The third modification was the fitting of a non-escape device to both creel eyes. The device, which is described in detail in "Practical Hints for Lobster Fishermen" (Scottish Home Department, 1952), consists of a hinged, freely movable, ∩-shaped, galvanized iron wire which at rest lies across the opening of the eye. It offers little resistance to entry of the creel but prevents escape through the eye. This type of creel is referred to as the *non-escape.*

Figure 1. Lobster scoop of diameter 4 ft.

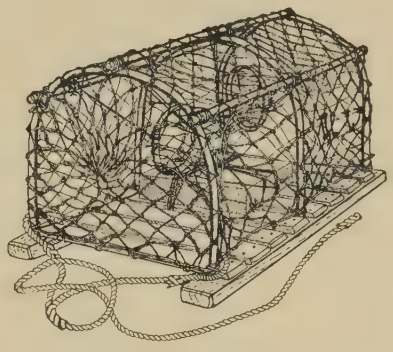


Figure 2. Lobster creel of *standard*, double open-eyed type.

Table I.

Specification data of creels.

Width of base	16½″
Length of base	27″
Height	13½″
Length of eye inlet	8″
Diameter of eye	4½″ internal
Mesh of netting	75 mm. (1·4″ open square)

Twelve of each of the four types of creel, standard, fine-mesh, single-eyed, and non-escape, were used in every fishing. The forty-eight numbered creels were shot in six fleets, each of eight creels. Each half

fleet comprised one of each creel-type. The arrangement used is shown in Figure 3.

In every individual fishing fleets were shot in the same depth, as nearly as possible, and distributed along the coastline with a separation of about $^1/_4$ mile between fleets. The period of fishing was in general about 24 hours.

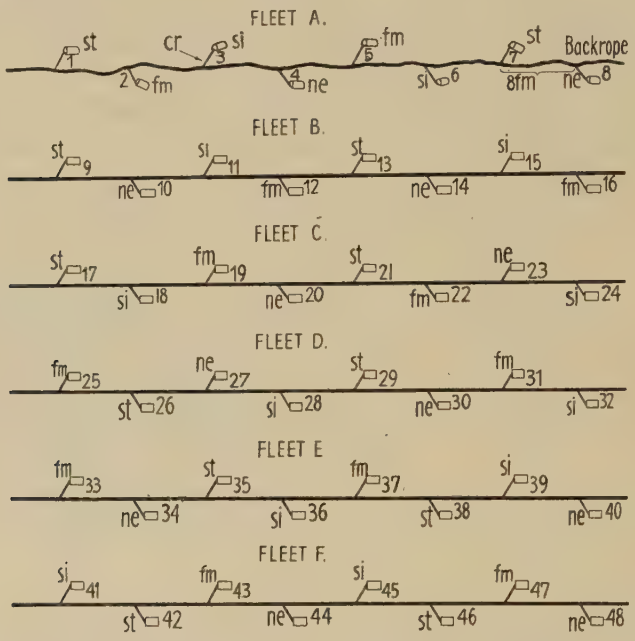


Figure 3. Arrangement of creel types. Each fleet comprises eight creels, two of each type. cr, creel rope, of length 2 fathoms; fm, fine mesh; ne, non-escape; si, single-eyed; st, standard creel type.

A variety of baits was used but all eight creels of any one fleet were invariably baited in the same manner for any one fishing. The fleets may therefore be taken as comparable units in the determination of the efficiency of the baits employed. Further, by this arrangement of baiting, each creel type is baited equivalently in any one fishing.

All lobsters caught were measured, with the abdomen fully extended, from the tip of the rostrum to the end of the telson (excluding the setae). Crabs were measured at the maximum width of the carapace.

III. The Size Selectivity of Creel and Scoop.

A total of 482 lobsters was refished from the storage pond at Bernera. The total population at the time of refishing was just over 20,000. Of the lobsters refished 284 were caught by creels whilst 198 were taken by scoops. All lobsters were measured to the nearest $^1/_4$ inch. Table II indicates the percentage length distribution by 1-inch

Table II.

The percentage length distribution of lobsters refished by creel and scoop.

Length range	7.5	7.75"-8.5"	8.75"-9.5"	9.75"-10.5"	10.75"-11.5"	11.75"-12.5"
Creels	0	3·9	10·9	22·9	25·7	23·9
Scoops	0·5	3·0	11·6	18·2	20·7	27·8

Length range	12.75"-13.5"	13.75"-14.5"	14,75"-15.0"	16.5"	Mean length
Creels	10·9	1·8	0	0	11·08"
Scoops	14·7	2·0	1·0	0·5	11·36"

groups together with the mean length as calculated from the full data (see appendix (a), Table X).

A "t"-test was carried out, the details of which are given in the appendix (a). The results indicate that the difference between the mean length of lobsters, caught by creels and scoops respectively, is significant at the 5 % level. This means that in not more than five times out of a hundred trials could such a difference be expected by mere chance, so that we can regard the difference as being reasonably significant.

The observed difference between the mean length of lobster caught by the creel and scoop, respectively, may be due to size selectivity in either or both devices. The dimensions of the creel eye will preclude entry of giant lobsters since it imposes a maximum size limit on lobsters which can be caught in the creel. There is no such obvious size limit in the case of the scoop. Whilst the creel caught no 15-inch or 16-inch lobsters (Table II), the scoop caught lobsters in both these groups, which suggests that the larger lobsters, present in the population, tend to be excluded from the creel. The length range of lobsters taken by means of the scoop is wider in both lower and upper limits, though more so in the latter, which fact supports the hypothesis that the scoop is the less selective of the two types of gear.

This hypothesis is further supported by a comparison of the results of the 1948—49 commercial refishing operations carried out at the Bernera pond, where refishing was by means of the scoop, and at a similar lobster pond at Stockinish, Isle of Harris, where creels were employed. Table III shows the average weight of lobsters refished during each month of the season. Whilst the average weight of lobsters taken by scoop remains almost constant, the mean weight taken by creel refishing shows an increasing trend throughout the period.

Table III.

Monthly average weights in lb. of lobsters refished during 1948—49.

	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.
Bernera pond — scoop	—	1·24	1·30	1·23	1·24	1·24	1·16	—
Stockinish pond — creel	1·23	1·32	1·42	1·41	1·50	1·42	1·46	1·53

In so far as these figures are adequate there is reason to believe that, over the size range of lobsters present in the pond, the scoop is non-selective.

Figure 4, which relates to the same data as Table II, shows the smoothed curves for number of lobsters taken by creel and scoop respectively in one-inch groups at $^1/_4$ in. intervals.

The close fit of the two curves over the length range $8^1/_4$ in. to $10^1/_2$ in. is striking and it can reasonably be assumed that over this range both devices are sampling the stock equally. There is a progressive falling off in the efficiency of the creel, vis-a-vis the scoop, in respect of lengths over $10^1/_2$ in., whilst for lobsters of length $12^1/_2$ in. to 14 in. the creel is little better than half as efficient as the scoop.

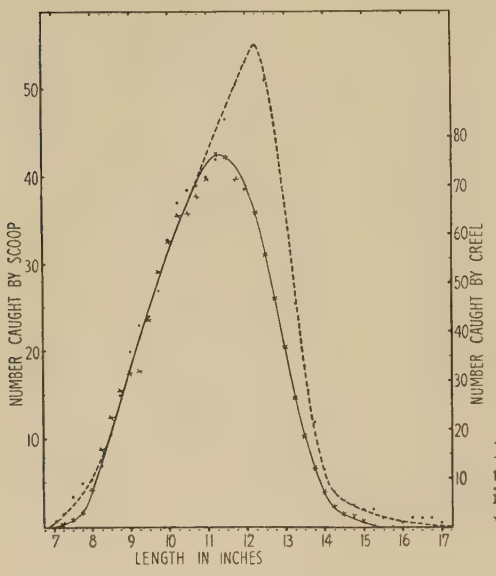


Figure 4. Number of lobsters taken by creel and scoop, respectively, in 1″ groups at ¼″ intervals (smoothed curves).

The somewhat lower efficiency of the creel, as compared with the scoop, in taking lobsters of lengths 8 in. and less is probably due to the more ready escape of this class through the eye as compared with lobsters of $8^1/_4$ in. and over (see also section IV, (c)). On account of the short duration of fishing, which was about $1^1/_2$ hours, this factor may have had only a small effect in determining the length distribution of lobsters caught in this experiment, but the question of such escapes may have greater significance in the commercial fishery.

IV. The Fishing Efficiency of Creel Types.

The position at which creel fishing was carried out was determined primarily in order to catch lobsters. However, crabs occur together

with lobsters on most grounds and, in general, varying numbers of both were captured. In considering the relative fishing efficiencies of the four creel types, in regard to lobsters, those fishings in which a total of only four or fewer individuals were caught, by the 48 creels, have been omitted. Similarly in the case of crabs, which were taken in larger numbers than lobsters, fishings have been excluded in which the total catch did not exceed nine.

(a) The Efficiency of Creel Types in the Capture of Crabs.

Table IV indicates the catch of crabs by creel types, being the sums of the catches from the twelve individual creels of each type, from all fleets for each of twenty-five fishings. The mean catch per fishing is also shown.

Table IV.

Catch of crabs by creel types per fishing.

	1	2	3	4	5	6	7	8	9	10	11	12	13
Standard	10	21	36	15	11	22	18	11	7	14	13	17	17
Fine-mesh	8	22	38	16	18	22	11	14	2	20	13	26	17
Single-eyed	8	10	27	7	9	13	10	10	7	16	11	17	9
Non-escape	8	19	17	18	15	18	10	7	5	23	17	27	6

	14	15	16	17	18	19	20	21	22	23	24	25	Mean
Standard	12	15	15	21	11	14	9	12	8	4	14	11	14·3
Fine-mesh	13	6	19	13	7	20	16	5	16	4	18	10	15·0
Single-eyed	17	13	4	18	5	21	7	9	10	1	13	8	11·2
Non-escape	18	16	19	16	8	21	4	9	14	1	13	7	13·4

An analysis of variance was carried out, the details of which are given in appendix (b). The results indicate that the differences between the mean catches of the individual creel types are significant at the 1 % level. In other words, the probability is less than 1 % that the observed differences between the mean catches of the four individual creel types have arisen by pure chance. The mean number of crabs caught by the single-eyed creels is significantly less than that caught by either the standard or the fine-mesh.

(b) The Efficiency of Creel Types in the Capture of Lobsters.

Table V indicates the catches of lobsters by the four creel types in each of nineteen fishings. The mean catch per fishing is also shown.

Table V.

Catch of lobsters by creel types per fishing.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	Mean
Standard	1	2	0	6	3	2	4	3	0	2	2	4	2	3	5	2	4	4	3	2·7
Fine-mesh	4	1	1	5	4	7	6	4	2	2	2	3	3	2	10	1	6	7	5	3·9
Single-eyed	1	1	2	6	5	3	4	2	2	1	0	2	0	7	5	2	2	6	5	2·9
Non-escape	3	1	4	3	3	2	3	5	1	2	4	2	0	4	4	4	6	3	6	3·2

With lobsters as with crabs the mean catch per fishing by the double open-eyed creel, the lower part of the eye-inlet of which has been lined by fine-mesh netting is above the average catch.

(c) The Size Selectivity of Creel Types.

In the light of the size selectivity shown by creels as compared with scoops (section III above) a test was carried out to determine if the various creel types show differential size selectivity.

A weighted estimate of the overall mean length of lobsters caught is given in respect of each creel type in Table VI. The figures are based on the results of fifteen fishings and take account of the fact that different numbers of lobsters were caught by each creel type in the individual fishings.

Table VI.

Weighted mean lengths in mm. of lobsters caught by creel types.

Creel	Standard	Fine-mesh	Single-eyed	Non-escape
Mean	276·0	283·2	258·8	279·9

An analysis of variance was carried out to test the significance of the difference in mean lengths of lobster caught by the four types of creel. Allowance was made in this analysis, the details of which are given in appendix (c), for the fact that the number of observations used to determine each mean is not constant. The results indicate that the differences in respect of the four creel types collectively are significant at the 5 % level. The lowest average size of lobster is caught by the single-eyed creel and this differs significantly from both the non-escape and the fine-mesh creels.

The double open-eyed creel types, namely fine-mesh and standard, retain larger lobsters than the single-eyed creel. It has been shown above (section IV) that the creel tends to restrict the entry of lobsters of over $10^1/_2$ in. more than specimens of less than this length, while giant lobsters are excluded by the dimensions of the creel eyes. In the course of other experiments it has been observed that where lobsters are put out in open-eyed creels, a proportion escape. It is reasonable to suppose that, for lobsters which are unable to pass through the mesh of the netting, both with entry and with escape the smaller the individual the easier is passage through the eye. Furthermore, the double open-eyed creel offers a greater chance of ecape than does the single open-eyed creel. The non-escape device deters the entry of the creel by smaller lobsters more so than larger individuals.

Table VII.

Weighted mean carapace widths in mm. of crabs caught by creel types.

Creel	Standard	Fine-mesh	Single-eyed	Non-escape
Mean	112·8	113·1	110·6	108·5

Table VII gives a weighted estimate of the overall mean carapace widths of crabs caught by creel types. The figures are based on the

results of eighteen fishings. An analysis of variance was carried out using the same method as was employed in the case of lobster lengths. The results, which are given in appendix (c), indicate that the differences betwen mean widths of carapace of crabs caught by the four creel types are significant at the 5 % level. The mean carapace width is lowest for the non-escape creel and is significantly less than those for the standard and the fine-mesh creels respectively. As with lobsters, both the double open-eyed creel types retain the larger crabs. The single-eyed creel is intermediate between the open-eyed creels and the non-escape creel.

The selectivity in respect of size of crabs caught by the double open-eyed creels, single open-eyed creels and non-escape creels, as shown above, can most probably be attributed to the more ready escape through the eye of the smaller crabs from the double open-eyed creels as compared with the single open-eyed creels and of the latter as compared with the non-escape creel. This interpretation is in agreement with the observed similarity in the size of crab retained by both the standard and the fine-mesh double open-eyed creels.

V. The Relative Fishing Efficiency of Baits.

The bait employed in commercial creel fishing varies according to the district. A number of factors decide the selection of the bait employed, of which the chief are local availability, suitability, and tradition.

Off the Berwickshire coast freshly caught flatfish are regularly used and it is seldom that resort is made to salted bait. On the other hand salted mackerel is widely employed on the west coast of Scotland where also freshly caught skate is occasionally used, when available. The latter, however, is never employed in Orkney. Further afield in the Channel Islands, limpets constitute the usual bait, though they are scarcely ever used in Scotland.

In the experimental fishing carried out by the Research Vessel "Kathleen" a variety of baits was employed. In any fishing the eight individual creels of a given fleet were baited similarly. Baits were varied between the six fleets. Salted plaice was used as a standard and was invariably set as a bait in at least two fleets. Against this standard other baits, which included freshly caught plaice and freshly caught skate, were compared.

(a) The Efficiency of Baits in the capture of Lobsters.

Table VIII shows the mean catches of lobsters, per fleet of eight creels, for each of three baits on eleven fishings carried out between May and August inclusive. The overall mean catch per fleet for each variety of bait is also shown. The entry in brackets indicates the number of observations upon which each mean is based.

The overall mean catch per fishing by fleets baited with freshly caught plaice is seen to be more than twice as great as the catch by

Table VIII.

Mean catch of lobsters per fleet by baits and fishings.

(The entry in brackets denotes the number of observations upon which each mean is based).

	1	2	3	4	5	6	7	8	9	10	11	Over-all mean
Salted plaice	0·0 (2)	0·0 (2)	0·5 (2)	2·0 (2)	0·5 (2)	1·0 (2)	0·0 (2)	1·5 (2)	2·0 (2)	1·5 (2)	1·0 (2)	0·91
Fresh plaice	0·3 (3)	1·3 (3)	6·3 (3)	3·5 (2)	1·0 (2)	0·0 (2)	1·0 (2)	3·0 (2)	5·5 (2)	3·0 (3)	1·0 (3)	2·35
Fresh skate	1·0 (1)	3·0 (1)	0·0 (1)	2·0 (1)	0·0 (1)	0·0 (1)	0·0 (1)	2·0 (1)	2·0 (1)	2·0 (1)	0·0 (1)	1·09

fleets baited with salted plaice or freshly caught skate. The latter two baits appear to be of about equal efficiency.

An analysis of variance was carried out as in the case of the size selectivity of creel types (appendix (c)). The results indicate that the difference between the overall mean catches using freshly caught plaice and salted plaice baits is significant at the 5 % level.

(b) The Efficiency of Baits in the Capture of Crabs.

Table IX shows the mean catches of crabs, per fleet of eight creels, for each of three baits on twelve fishings carried out between May and August inclusive. The overall mean catch per fleet for each bait is also shown. The entry in brackets indicates the number of observations upon which each mean is based.

An analysis of variance was carried out using the method employed in the analysis of the size selectivity of creel types (appendix (c)). The difference between the overall mean catches using freshly caught skate and salted plaice and the difference between freshly caught plaice and salted plaice are each significant at the 1 % level.

Freshly caught skate and freshly caught plaice were individually more efficient baits for the capture of crabs than salted plaice at the time of this experiment.

Table IX.

Mean catch of crabs per fleet by baits and fishings.

(The entry in brackets denotes the number of observations upon which each mean is based).

	1	2	3	4	5	6	7	8	9	10	11	12	Overall mean
Salted plaice	2·0 (2)	1·0 (2)	0·0 (2)	8·5 (2)	8·5 (2)	4·0 (2)	4·0 (2)	2·0 (2)	6·0 (2)	8·0 (2)	8·5 (2)	1·5 (2)	4·50
Fresh plaice	13·0 (3)	12·0 (3)	4·0 (2)	7·0 (3)	8·0 (2)	13·5 (2)	10·0 (2)	4·5 (2)	9·0 (2)	10·5 (2)	14·7 (3)	9·0 (3)	9·60
Fresh skate	6·0 (1)	4·0 (1)	9·0 (1)	35·0 (1)	14·0 (1)	23·0 (1)	9·0 (1)	36·0 (1)	15·0 (1)	7·0 (1)	7·0 (1)	1·0 (1)	13·83

VI. Discussion.

The evaluation of the fluctuations in a fish population, the effect of the fishery on the stocks, and the estimation of recruitment and of the total population are essential data in the investigation of any fishery (Russell, 1931). Accurate determination of these quantities is dependent on a knowledge of the efficiency of the sampling methods employed.

The chief source of data in the Scottish shellfish industry is the commercial landings, together with the relevant records of fishing effort in terms of creel-hauls. Additionally, in some cases, a length analysis of the catch is available. It is important, therefore, to know the significance of the measures obtained by these methods and how far the comparison of results, from year to year and area to area, is justifiable.

Comparison of creel and scoop (Figure 4) reveals a size selectivity which is certainly chiefly and probably wholly attributable to the former. The creel shows an increasingly lower catchability for lobsters of over $10^1/_2$ in. length as compared with those of lengths $8^1/_2$ in. to $10^1/_2$ in. Thus any determination of overall annual mortality based on the comparison of two length-groups using "marked" lobsters separated by a growth increment, within this length-range, will tend to overestimation.

In addition to the decreasing efficiency of the creel in its upper range, the creel has also a "cut off" in its lower range. Experiments carried out by Wilder on trap-lath spacing, and referred to by Needler (1948), suggest that the netting type of creel, with a 75 mm. mesh such as used in the experiments carried out by the F. R. V. "Kathleen", would retain lobsters of 8 in. and over, except those escaping through the eye. In our experiments small lobsters up to $8^1/_2$ in. were found less frequently in the creel as compared with the scoop (Figure 4). In the case of both lobsters and crabs the size selectivity of both the double open-eyed creel types as compared with the single open-eyed creels (Tables VI and VII) indicated the greater facility for escape of the smaller fish through the creel eye.

In the case of lobsters the above results suggest that over the length-range $8^1/_2$ in. to $10^1/_2$ in. the creel affords a comparable assessment of the lengths of lobsters on the grounds. Length distributions for lobsters caught by creel at six stations around the Orkney group of islands are shown in Figure 5. Similar data for the English fishery are given by Graham (1949) and other Scottish data by Thomas (1951). Typically the 8-inch to 9-inch length-group is less than the 9-inch to 10-inch group which in turn is less than the 10-inch to 11-inch group. If, as seems to be the case, the creel is uniformly efficient in catching lobsters over the greater part of this length-range, it follows that there are in fact more 9-inch than 8-inch and more 10-inch than 9-inch lobsters on the Orkney fishing grounds, as in many other areas where fishing mortalities are moderate, say of about 25 % annually.

The moulting frequency of lobsters in Scottish waters, in the various size-classes, has not been determined. In the case of the American

lobster, which in general is very similar to *Homarus vulgaris*, Herrick (1896) records biannual moulting, in the spring and in the fall, for lobsters in the length-range 7 to $9^3/_4$ in. Templeman (1939) similarly records two moults annually in lobsters up to 9 in. On the other hand Corrivault and Tremblay (1948) record that, in the Grand River region, lobsters of over 18 cm. (7 in.) length do not moult more frequently than once per year, so that the moulting frequency probably varies from place to place. In the case of the European species of lobsters it seems probable, in general, that lobsters of between 8 and 9 in. moult biannually, a proportion of 9 to 10 in. lobsters may in certain years also moult biannually, mature male lobsters, of over 10 in., moult

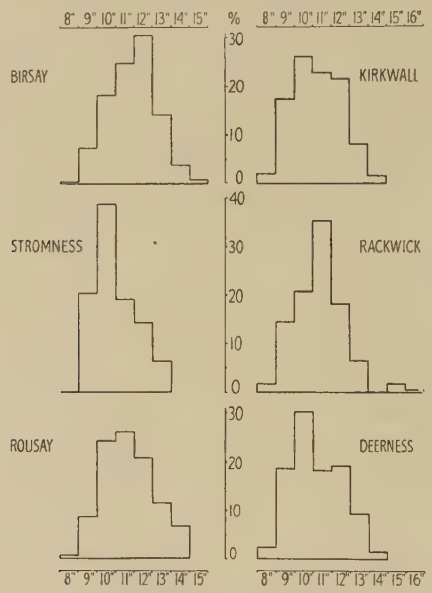


Figure 5. Percentage length distribution of lobsters landed at six stations around Orkney.

annually, while mature female lobsters of the same length moult every other year (Appellöf, 1909). This is, of course, a rough generalization about the stock as a whole, but it is in keeping with the observed proportions of the repective length-groups in the lobster populations around the coast of Scotland. A further possibility is that there is a continual migration of larger lobsters on to the fishing grounds from outside though this has not been substantiated by other work.

In making detailed comparisons of the lobster or crab populations between one area and another the relative fishing efficiencies of the creels employed is of importance. Considerable differences exist in types of creel used in the English fishery. Thus the creel typical of the north-east of England is similar in design to the type used throughout Scotland whilst being totally different from the half-spherical Cornish-type pot,

with apical eye, employed in the south-west areas. Apart from this major difference the less obvious differences between local creel types cannot be neglected. Examples of the effects of such differences are seen in the relative efficiencies of the fine-mesh, double open-eyed, non-escape, and single-eyed creels, investigated by the F. R. V. "Kathleen". Variations of similar nature are commonly incorporated in the creel types used in different areas of the Scottish fishery. The differences between these creel types relate to fishing efficiency both by number caught and by size (Tables IV, V, VI, and VII). A wide variety of baits is also employed in the commercial fishery and many of these will differ in fishing efficiency. All the above factors, unless evaluated, may be the source of inaccuracy in making comparison of populations between areas and possibly between one year and another in the same area.

The Scottish Home Department have suggested herring offal as a bait for creels (*Fishing News,* 1926). An artificial bait has also been developed (*Fishing Gazette,* 1947). A new type of creel of the Canadian pattern has been recommended to the Scottish lobster fishermen (Scottish Home Department, 1952). Wide differences exist in the creel types already in use in Britain. A detailed investigation of the relative efficiencies of these devices at different seasons and in different areas is required in order to develop the most efficient fishing gear and methods, as well as to assess the available populations, so as to develop a fishery in balance and at the most economic level.

VII. Summary.

(1) In sampling a lobster population by means of creels and scoops, at the same time, the average length of lobster caught in the creel is lower than that caught in the open scoop. Lobsters of over $10^1/_2$ inches length tend to be excluded by the creel, which is also less efficient in respect of small lobsters of 8 inches.

(2) In catching crabs creels fitted with fine-mesh netting were the most efficient of the four types used. Both the double open-eyed creel types are more efficient than single open-eyed creels.

(3) Of the four creel types investigated those fitted with fine-mesh (17 mm.) netting to the lower surface of the eye inlet caught more lobsters than did creels not so fitted.

(4) The mean size of lobsters landed by the single open-eyed creels is less than that for lobsters landed by both the fine-mesh double open-eyed creels and the non-escape creels. This is attributed to the greater chance of escape of small lobsters through the eye in the case of the double open-eyed creels as compared with the single-eyed creel, whilst the non-escape device deters the entry of the smaller more so than the larger lobsters.

(5) The mean size of crabs landed by the standard and fine-mesh double open-eyed creels is greater than that for the single open-eyed creel which is in turn greater than the mean size of crabs caught by the non-escape creel. These differences are attributable to the decreasing

ease with which small crabs escape, through the eyes, from the double open-eyed, the single open-eyed, and the non-escape creels respectively.

(6) In lobster fishing freshly caught plaice is a more efficient bait than salted plaice.

(7) In crab fishing freshly caught skate and plaice individually are more efficient baits than salted plaice.

(8) The significance of the above results in the estimation of population statistics is discussed.

VIII. Appendix. The Statistical Treatment of Results.

(a) The Size Selectivity of Creel and Scoop.

In order to test the significance of the difference between mean lengths of lobsters caught by creels and scoops respectively, a "t"-test was carried out on the data given in Table X. The difference was found to be significant at the 5 % level ($t = 2{\cdot}16$, d. f. $= 480$). The scoops caught larger lobsters than the creels.

Table X.

The number of lobsters caught by creel and scoop, respectively, by lengths.

Length (in.)	Number caught By Creel	By Scoop	Length (in.)	Number caught By Creel	By Scoop
7·5	0	1	11·5	21	17
7·75	1	1	11·75	18	7
8·0	1	3	12·0	18	18
8·25	2	0	12·25	14	9
8·5	7	2	12·5	18	21
8·75	11	3	12·75	11	7
9·0	4	8	13·0	8	10
9·25	10	4	13·25	6	7
9·5	6	8	13·5	6	5
9·75	13	3	13·75	2	0
10·0	23	10	14·0	1	3
10·25	11	8	14·25	0	1
10·5	18	15	14·5	2	0
10·75	11	5	14·75	0	0
11·0	26	11	15·0	0	2
11·25	15	8	16·5	0	1

(b) The Efficiencies of Creel Types.

The relative efficiencies of creel types were determined by a statistical analysis of the number of crabs and lobsters respectively which were caught. An initial analysis revealed the existence of a correlation between the mean values of the groups of observations which were to be compared and the variance within these groups. Accordingly it was necessary to transform the observations before carrying out a detailed analysis (Bartlett, 1936). The following transformation, suggested by Anscombe (1948), was adopted:—

$$y \quad \sqrt{\left(x + \frac{3}{8}\right)}$$

Table XI.

The analysis of variance of numbers of crabs and lobsters caught by creel types.

A. Crabs.

Source of variation	d. f.	S. of S.	M. S.	V. R.
Between creel types	3	3·793	1·264	4·17*
Between fishings	24	58·971	2·457	8·11**
Error	72	21·823	0·303	—
Total	99	84·587	—	—

B. Lobsters.

Source of variation	d. f.	S. of S.	M. S.	V. R.
Between creel types	3	1·086	0·362	2·09
Between fishings	18	12·666	0·704	4·06***
Error	54	9·351	0·173	—
Total	75	23·103	—	—

Levels of significance are denoted by asterisks: one asterisk denotes significance at the 5 % level of probability; two asterisks denote significance at the 1·0 % level; and three asterisks denote significance at the 0·1 % level.

The analyses in Table XI, A and B, show that differences between creel types is significant in the case of crabs but not in the case of lobsters.

As will be seen by reference to Table XII the mean numbers of crabs caught by the single-eyed creels are significantly less than that for the standard and fine-mesh types respectively ($P<0{\cdot}01$).

Table XII.

Transformed creel means and standard error in respect of numbers of crabs caught by creel types.

Creel type	Standard	Fine-mesh	Single-eyed	Non-escape
Mean	3·76	3·78	3·30	3·59

Standard error of differences between two means = $\pm 0{\cdot}156$ (d. f. = 72)

(c) The Size Selectivity of Creel Types and the Efficiency of Baits in the Capture of Lobsters and Crabs respectively.

The analysis of the mean lengths of lobsters and crabs, respectively, caught by the varying creel types and of the number of lobsters and crabs respectively caught by the varying baits presents more difficulty, for in these cases the means are based on different numbers of observations.

The method of analysis appropriate to such data depends on whether interaction between main effects is present or absent. If interaction exists it is necessary to use an analysis involving weighted sums of squares (S n e d e c o r, 1946). If interaction is not significant, constants may be fitted by the method of least squares to estimate the various effects.

An alternative to the method of least squares is to use dummy variables and carry out an analysis of covariance estimating partial regression coefficients in the usual way (Quenouille, 1950). The regression coefficients measure the deviations of the various effects from the general mean and their significance may be tested by the methods appropriate to a multiple regression analysis.

Interaction between main effects was found to be not significant and analyses of covariance were carried out. This has been used in conjunction with the transformation given in (b) above in the case of catches of lobsters and crabs respectively by baits.

(α) Size Selectivity of Creel Types in respect of Lobsters and Crab.

The details of the completed analysis in respect of lengths of lobsters caught by the creel types is given in Table XIII.

Table XIII.

The analysis of variance of the lengths of lobsters caught by creel types.

	d. f.	S. of S.	M. S.	V. R.
Days (eliminating creel types)	14	102,950·90	7,353·64	4·28***
Creel types (eliminating days)	3	14,461·59	4,820·53	2·80*
Days and creel types	17	111,791·01	—	—
Interaction	42	66,159·57	1,575·23	—
Sub-groups	59	177,950·01	—	—
Error	117	201,160·69	1,719·32	—
Total	176	379,111·27	—	—

See note to Table XI.

The differences between lengths of lobsters caught by the creel types are significant at the 5 % level of probability. The creel type means are shown in Table VI. Table XIV gives the differences between these creel type means along with the appropriate standard errors for testing these differences. The table also gives the corresponding data in respect of carapace widths of crabs.

Table XIV.

The standard errors and the differences between means in respect of A lengths of lobsters and B of carapace widths of crabs caught by creel types.

Creels being compared	A. Lobsters. Difference between means	A. Lobsters. S. E.	B. Crabs. Difference between means	B. Crabs. S. E.
Standard — Fine-mesh	— 7·2	8·84	— 0·3	1·82
Standard — Single-eyed	+ 17·2	9·56	+ 2·2	1·97
Standard — Non-escape	— 3·9	9·62	+ 4·3	1·86*
Fine-mesh — Single-eyed	+ 24·4	8·84*	+ 2·5	1·95
Fine-mesh — Non-escape	+ 3·3	8·86	+ 4·6	1·83*
Single-eyed — Non-escape	— 21·1	9·48*	+ 2·1	1·98

See note to Table XI.

The analysis shows that the mean length of lobsters caught by the single-eyed creel is significantly lower than that caught by the fine-mesh and the non-escape creels respectively, and further, that the mean carapace width of crabs caught by the non-escape creels is significantly less than those for both standard and fine-mesh creels respectively.

(β) The Efficiencies of Baits in the Capture of Lobsters and Crabs.

Table XV gives the transformed means in respect of numbers of lobsters and crabs respectively caught by baits, and Table XVI gives the differences between these means along with the appropriate standard errors for testing these differences.

Table XV.

Transformed mean numbers of A lobsters and B crabs caught by baits.

Bait	A. Lobsters.			B. Crabs.		
	Salted flatfish	Fresh flatfish	Fresh skate	Salted flatfish	Fresh flatfish	Fresh skate
Mean	0·72	1·42	0·86	1·89	3·07	3·50

Table XVI.

The standard errors and the differences between the transformed means in respect of numbers of A lobsters and B crabs caught by baits.

Baits being compared	A. Lobsters.		B. Crabs.	
	Difference between means	S. E.	Difference between means	S. E.
Salted flats — Fresh flats	— 0·70	0·19*	— 1·18	0·24**
Salted flats — Fresh skate	— 0·14	0·24	— 1·61	0·31
Fresh flats — Fresh skate	+ 0·56	0·24	— 0·43	0·30

The analysis shows that fresh flatfish caught more lobsters than salted flatfish and that fresh flatfish and fresh skate each caught more crabs than salted flatfish.

IX. References.

Anscombe, F. J., 1948. "The transformation of poisson, binomial and negative-binomial data." Biometrika, Vol. 35, pp. 246—254.

Appellöf, A., 1909. "Untersuchungen über den Hummer, mit besonderer Berücksichtigung seines Auftretens an den Norwegischen Küsten." Bergens Mus. Skr., N. S., Bd. 1, No. 1, pp. 1—79.

Bartlett, M. S., 1936. "Square-root transformations in the analysis of variance." J. R. Statist. Soc., Supp. 3, pp. 68—78.

Corrivault, G. W., & Tremblay, J. L., 1948. "Contribution à la biologie du homard dans la Baie-des-Chaleurs et le golfe Saint-Laurent." Contr. Sta. Biol. St.-Laurent, P. Q. Canada, No. 19, pp. 1—222.

Scottish Home Department, 1952. "Practical hints for lobster fishermen." H. M. S. O., pp. 1—16.

Fishing Gazette, N. Y., 1947. "A new type lobster lure." Vol. 64, No. 2, pp. 61 and 92.

Fishing News, 1926. "Lobster experiments." July 24, Vol. 14, No. 686, p. 5.

Graham, Michael, 1949. "A Note on the theory of a dwarf race of lobsters on the Norfolk Coast." J. Mar. Biol. Ass. U. K., Vol. 28, pp. 481—487.

Herrick, F. H., 1896. "The American lobster: a study of its habits and development." Bull. U. S. Fish. Comm., 1895, Vol. 15, pp. 1—252.
Needler, A. W. H., 1949. "Report for 1948 of the Atlantic Biological Station, St. Andrews, N. B." Rep. Fish. Res. Bd. Canada, 1948, pp. 30—39.
Quenouille, M. H., 1950. "Computational devices in the application of least squares." J. R. Statist. Soc., Ser. B, Vol. 12, No. 2, pp. 256—272.
Russell, E. S., 1931. "Some theoretical considerations on the 'overfishing' problem." J. Cons. Int. Explor. Mer, Vol. 6, pp. 3—20.
Snedecor, G. W., 1946. "Statistical methods." 4th ed., Collegiate Press, Iowa.
Templeman, W., 1939. "Investigations into the life history of the lobster *(Homarus americanus)* on the west coast of Newfoundland, 1938." Res. Bull. Newfoundland Dept. Nat. Res., No. 7.
Thomas, H. J., 1951. "Fluctuations in the lobster *(Homarus vulgaris)* population of the Scottish Coast." Rapp. Cons. Explor. Mer, Vol. 128, II, pp. 84—91.

Letters to the Editor.

Correlations on Fisheries Hydrography.

Lowestoft, 14th July 1952.

Dear Sir,

Recently there have been a number of papers by Carruthers *et al.* which have deduced remarkably close correlations between certain functions of wind strength at the time of spawning and the subsequent brood strength for several species of fish, including herring, cod, and hake. Graham, for the cod, has commented adversely on the biological implications of these results, but there is a statistical aspect which I feel is of fundamental importance and of quite wide application, and which has not been sufficiently noted. In these papers the probability of as good a correlation arising by chance, if the two variables (wind conditions and brood strength) are entirely independent, has not been stated, but unless this probability is known to be small, the apparent existence of a correlation cannot give any sure information on the interdependence of the two events; also, of course, no correlation, however close, can of itself establish two events as being cause and effect.

For ordinary linear correlations between unadjusted observations the required probability is easily evaluated, and is given in most statistical text-books, but the more complex methods used in these papers make an exact evaluation of the probability difficult. However, it may well be large, and to show this I have applied the methods to data known to be independent, taking a set of 50 random numbers from Fisher and Yates's *Statistical Tables* (Table XXXIII).

Essentially, the method consists in plotting the estimated brood strength of the fish for each year against some corresponding function of the wind for some period in the spawning season. Often this period varies from year to year, not because of direct observation of the spawning period, but because, to quote:— "This correlation... would be strengthened by assuming that the hake sometimes spawned early". The particular choice of period is later related to certain other hydrographical conditions. A freehand curve is then drawn through the plotted points to give as good a fit as possible.

Table I.
Random Numbers.

A	B_1	B_2	B_3	C	B
36	96	47	36	61	36
42	81	14	57	20	81
56	50	26	71	7	50
96	96	68	27	31	68
38	54	82	46	22	82
49	54	43	54	82	43
57	24	55	6	88	55
16	95	55	67	19	95
78	64	56	7	82	56
9	47	27	96	54	96

The random numbers are shown in the table. Column A may represent "brood strength" over 10 years; columns B_1, B_2, B_3, the "wind" for three alternative periods in the spawning season; column C, the "wind" for some previous period. The values of B_1, B_2, and B_3 are plotted against A in Figure 1. As expected, the points are well scattered and exhibit no marked relationship.

Now select B_1 if $C \leqq 20$
B_3 if $50 < C \leqq 65$
B_2 otherwise

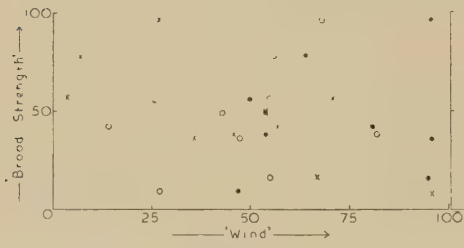


Figure 1. $B_1 = \bullet$; $B_2 = o$; $B_3 = \times$.

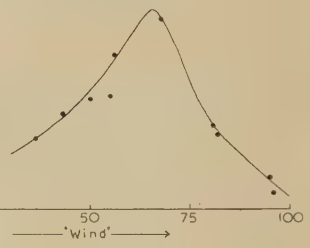


Figure 2.

The values B thus selected are plotted in Figure 2. A suitable freehand curve is drawn in, giving a very striking result. Without critical examination, the evidence that there is a very close connexion between "brood strength" and "wind" seems conclusive, the best "brood" occurring for a "wind" strength of 65, falling off rapidly on either side.

Compare with this result the correlations obtained for the herring by Carruthers, Lawford, and Veley, Figures 4 and 8. The fits obtained are roughly equally good; if anything, that obtained from random numbers is the best, taking into consideration the fact that the correlation of Figure 4 has had to be presented in two parts, for $S < W$ and $S > W$. The degree of adjustment used is similar; for the herring a somewhat involved function of two variables, west and south wind, is used instead of a single reading; the four periods, January, January/February, and February, February/March, correspond to colums B_1, B_2, B_3, and the west wind for December to column C, the former being divided into eight; the latter, four classes. The degree of adjustment used is shown by the choice of west wind component; this is chosen for January if D, the December west wind component, is $> 6{\cdot}8$;

for January/February if $6{\cdot}15 < D < 6{\cdot}8$ or $4{\cdot}9 < D < 5{\cdot}6$;
for February if $5{\cdot}6 < D < 6{\cdot}15$ or $2{\cdot}2 < D < 4{\cdot}9$ or $-1{\cdot}3 < D < 0$,
and for February/March if $0 < D < 2{\cdot}2$ or $D < -1{\cdot}3$.

The reason why such striking correlations are found is that instead of finding the correlation (in its strict statistical sense, and which is a linear relationship) between simple pairs of values of brood strength and wind, both the relationships and the set of values to be correlated are *selected* from a very large number of such relationships and sets. If the wind can be chosen from any one of three possible spawning periods, then over, say, 14 years the number of possible sets of wind values is 4,782,969, and once a particular choice is made, and provided the number of years is not too large, then a justification for this choice is easily found.

In choosing the function of the wind to be correlated the choice is also wide even with very simple functions, especially if there are two or more independent wind variables, e.g., west and south wind. For example, the following functions have been used:—

$$\sqrt{S^2 + E^2} \sim \sqrt{N^2 + W^2} \quad \text{for the haddock}$$

$$\sqrt{S^2 + W^2} \quad \text{for the herring}$$

$$\sqrt{(S^2 - N^2)^2 + (W - E)^2} \quad \text{for the plaice}$$

$$W - E \quad \text{for the hake}$$

and an apparently different but not explicitly stated function for the sprat.

For the actual relationship between brood strength and wind over any given set of years, it is always possible to calculate any number of functions giving curves passing exactly through all the points. The simplest function that can be calculated depends on how many points, i.e., years, are used. A straight line can always be drawn through two points, a circle through three, a conic through five, a cubic through nine, and a quartic (using terms up to the fourth degree) through fourteen points. That is, once curves other than a straight line are used, the number of points through which a mathematically defined curve can be made to pass exactly increases rapidly. Freehand curves merely sketched in can be drawn to pass through any number of points, and in this case it is only necessary to find a curve to pass reasonably close to each point. Returning to the case of 14 years, it is not surprising that with four million different sets of points, there is at least one set for which all the points lie on or near a reasonably smooth curve.

The above is an example of what could well be expected on common-sense grounds alone; viz., that if a set of observations of two independent variables is suitably adjusted to get the best possible correlation, then a close correlation will appear, and in fact for a short series of observations the required degree of adjustment will probably be small.

The papers referred to state an ingenious theory about the important and little-understood problem of year-class fluctuations, but the correlations obtained may well have occurred purely by chance, and can therefore give little support to the theory, nor can they refute the alternative null hypothesis that wind and brood strength are independent.

Yours truly,

J. A. Gulland.

Winds and Fish Fortunes.

London, 31st July 1952.

Dear Sir,

Please allow us to make a partial reply to the Letters to the Editor printed on page 73 of your issue of April 1952.

Our "general approach" has been as set out in that essay by one of us (J. N. C.) which appeared in the Sears Foundation's *Journal of Marine Research* (Vol. X, No. 1, 1951) entitled "An Attitude on Fishery Hydrography". Crudely put, the thesis was that annual fish fortunes can hardly fail to be materially dependent upon those year-from-year differences in the total commotion of the sea which can be attributed to the year-from-year differences in the wind conditions which reigned during the individual spawning seasons. Inferring that Mr. S i m p s o n has little liking for that thesis, we would make a few pertinent observations:—

1) We believe that it will never be possible adequately to keep track of all the fluctuating individual factors which may separately influence upgrowth.
2) We regard it as of little importance if some "explanations" advanced *within* our thesis are demolished.
3) We hold that far too little thought has been given to possible distributions of larvae, etc. in the sea at times and places when and where a single research vessel cannot be present.
4) We attach great importance to the fact that wind is the only factor we know *all the time* and (as we have inferred it) over the whole of an area.

We regard Mr. G r a h a m's criticisms as apparently destructive of one of our "explanations" (see 2 above) but see in it nothing destructive of our demonstration that good or poor fishable populations have frequently arisen, a certain number of years after, from such-and-such wind conditions.

Of the many points on which we could join issue with Mr. G r a h a m in the case of the cod, we choose only one. The "supposedly critical drift" matters nothing. We considered a centroid of the northern spawning areas since we had to start from somewhere. Had we taken the centroid at any other position we should still have found that in good years the destinations of the cod fry, as inferred from the wind drift, lay in a small area to the northward, while in bad years they were widely dispersed away from the "good" area.

The whole current pattern of the North Sea changes with the wind with implications which should be obvious. As V a r e n i u s said long ago, "Si pars oceani movetur, totus oceanus movetur", and the eddy cannot be assumed permanent in position.

The main substance of Mr. Gulland's letter, which appears in the present issue, is a criticism of the correlation methods used in our herring analysis. The haddock analysis is only lightly touched upon; nevertheless, it was the significant results first revealed by that analysis which encouraged us to apply the same basic principles to studies of other North Sea fish.

Veley now points out that the correlation obtained for haddock with the function $\sqrt{S^2+E^2} \sim \sqrt{N^2+W^2}$ always employs the *same* spawning months in the evaluation of the function. A period of 28 years, covering 1917—1938 and 1945—1950, was embraced, within which the brood values for 1917—1919 only are open to doubt. During this long period only three serious deviations from the predicted values occurred, and discussion with the Scottish Home Department's Marine Laboratory at Aberdeen has suggested possible explanations for two of them. Research is now being carried out by that Laboratory which may either support or destroy our tentative biological interpretation of the correlation. Furthermore, it has never been claimed that a reliable method of predicting haddock brood strengths has been established, but rather that our work has pointed the way to a possible line of research hitherto untouched.

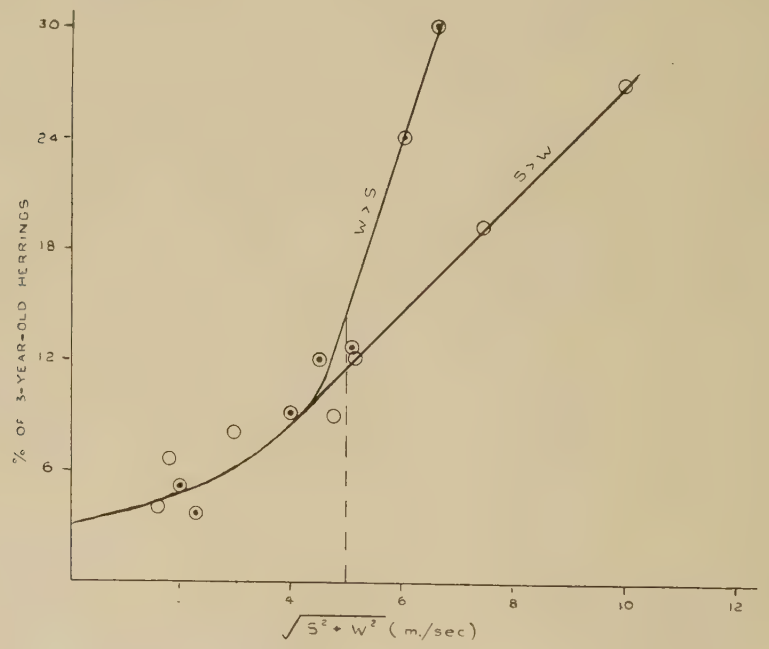
In the case of the herring, it seems clear that Mr. Gulland has not sufficiently appreciated that the function $\sqrt{S^2+W^2}$ stands good, in our original paper, for 25 separate pairs of values, not merely for 10 as illustrated in his mathematical example nor for the 14 he refers to. The 25 pairs comprise, in fact, 14 for the East Anglian herring and 11 for the Belgian spent-herring fishery. The same function is used for both, but for biological reasons stated in the original paper the months chosen for the spent herring are one previous to those for the East Anglian fishery. For example, for 1929, which is common to both analyses, the months selected for the south and west wind components are January and January/February respectively in the case of the East Anglian herring; for the spent herring the months are December and December/January. A positive correlation is revealed for the former fishery and a negative for the latter, results which were foreshadowed in earlier work by Carruthers[1]) carried out at Lowestoft.

In his example, Mr. Gulland employs three variables B_1, B_2, B_3, whose selection is governed by a fourth variable C. With ascending values of C the variables are selected in the order B_1, B_2, B_3, and again B_2. Veley emphasizes that, while all these variables are random, in our herring analysis the corresponding variables are in strict chronological sequence with descending values of their governing variable. It is possible, therefore, that Mr. Gulland has not discerned that the order in which we selected the months for the south and west wind components is logical. The following table may make this clearer:—

[1]) Carruthers, J. N., — "Fluctuations in the Herrings of the East Anglian Autumn Fishery, the Yield of the Ostend Spent Herring Fishery, etc." — R. et P.-V., **107**, 1938 (III, 2).

West Wind Component for December	Month(s) selected for South Wind Component	Month(s) selected for West Wind Component
Decreasing ↓	January	January Jan./Feb. February
	Jan./Feb.	Jan./Feb. February Feb./Mar.
	February	February Feb./Mar.

In other words, in each group the selected west wind month starts by being the same as for the south wind month, and with decreasing *December* west wind it moves forward in half-month steps until it is one month after the south wind month. The latter then moves on half a month, and the sequence is repeated. Thus the mathematical example is not a true parallel.



ANALYSIS OF ASSOCIATION BETWEEN HERRING BROODS AND $\sqrt{S^2 + W^2}$

Mr. G u l l a n d next deprecates our presentation of the analysis for the East Anglian herring being in two parts. In the accompanying figure the two parts of our Figure 4 have been combined, and it is seen that for low values of the wind function (below about 5 m./sec.) the two curves merge. It is only for the high values that a divergence appears,

and it was to illustrate this divergence, for which a possible explanation was advanced on physical grounds, that the analysis was presented in two parts.

It is appropriate here to consider why it is necessary to employ a modification (December west wind component) in the case of the herring and none in the case of the haddock. We had no knowledge of notable haddock spawning migration, and therefore the same months (February to May) were used when evaluating the wind function. Since the herring, however, migrates southwards towards the Straits of Dover and passes through to the French coast, any variation in the time of arrival of the main body of spawners off Cap d'Antifer will surely give rise to variation in the time of the spawning peak. From the scanty evidence we could discover it appeared that variations do occur, and it would be imprudent, therefore, to consider the *same* period of each year for evaluation of the wind function, when for many years there might in fact be no appreciable spawning during part of that period. Use, then, has been made of the finding by H o d g s o n, that "the main body of herrings always move in a direction opposed to the wind", in attempting to make provision for variation in the time of the spawning peak. Thus a modification was introduced for the herring and other fish which make spawning migrations, such as the plaice and hake, but not for the haddock, cod, and sprat.

Referring to the final section of Mr. G u l l a n d' s letter, it is of course undeniable that, with three possible spawning periods, the number of possible sets of wind values for a period of n years is $3n$, but it is hard to see how this is relevant to the argument. For instance, for a period of 28 years the possible sets would number some 20 billion. In other words, there is a far greater selection over 28 years than over 14, which on Mr. G u l l a n d' s arguments would inevitably lead to the conclusion that the greater the number of years for which a correlation is to be attempted, the easier it is to find it. This is obviously a reduction to the absurd, since for a period of two years nine perfect correlations, in the general case all different, can be obtained.

One further point. For wind functions above about 5 m./sec. the regression lines in Figure 4 are straight, and below this value there is an asymptotic approach to the wind function axis; both curves cut the herring axis at the same value of 3 %. This would all be as expected; the combination of initial curve followed by a straight line is commonly found in nature. Moreover, in Figure 8 the negative curvilinear regression line is a close approximation to the rectangular hyperbola $(x - 2{\cdot}4)(y - 1500) = 35{,}000$, which is determinable by only three points; this is another anticipated result. Thus in this analysis covering 25 points no curve of degree higher than conic has been used, and certainly none to compare with that exhibited in the mathematical example. In the plaice analysis all regression lines are straight.

Summing up, the function $\sqrt{S^2+W^2}$ accounts for brood variations in the East Anglian fishery between 1921 and 1936, agrees with the qualitative evidence supplied for 1942—1946 and also with the figure

for the 1948 brood. It disagrees with the figure given for the 1947 brood, but it has been suggested that this might be accounted for by the temperature conditions prevailing during that year's spawning period. As to the Belgian spent-herring fishery, the same function accounts for variations in catches over 11 years. Both qualitatively and quantitatively it thus covers 34 separate cases in two independent fisheries with only one misfit, a fact which seems hardly likely to be fortuitous. Moreover, the choice of spawning period is founded upon logical argument and not on a random selection.

Mr. Gulland's letter, therefore, while containing in its initial paragraphs statistical arguments which are beyond reproach, appears to have little application to the herring analysis.

The above has dealt in detail with Mr. Gulland's criticisms mainly from the mathematical viewpoint. The general question, of burning interest to the non-statisticians in this field of work, has always been, If a reasonable correlation can be established between fish events and environmental factors, is this automatically destroyed by a demonstration that an equally good correlation is obtainable between sets of random and totally unconnected figures? If it is, they should be comforted by being told why.

Yours truly,

J. N. Carruthers. *A. L. Lawford.* *V. F. C. Veley.*

Errata.

I. I. Schell. "On the Role of the Ice off Iceland in the Decadal Air Temperatures of Iceland, and some other Areas".
Vol. XVIII, No. 1, 1952.
p. 27, l. 12 and l. 14. For "—0·58°C.", read "—0·71°C."
p. 28, Table V, l. 4 of column "Archangel". For "—·58", read "—·71".
Table V, l. 2 of column "Difference". For "—·45", read "—·58".

Reviews.

G. A. Riley. "Parameters of Turbulence in the Sea." Journ. Mar. Res., **10**, 3, pp. 247—256, 2 figs. New Haven, Conn., 1951.

Turbulent mixing is a problem which concerns not only physical oceanographers but also those interested in the distribution of plankton and of chemical constituents in the sea. It was his studies of such problems which led Riley to seek relations between coefficients of eddy diffusion obtained under widely different conditions.

From data given in the author's previous papers, it appeared that both the vertical and horizontal eddy coefficients are proportional, other things being equal, to the square of the mean current speed. In water of indifferent stability, dimensional analysis leads to an equation for eddy diffusivity of the form

$$A = \frac{\alpha(\varrho v x)^2}{\mu}$$

where α is a constant, ϱ is the density and μ the molecular viscosity of the water, v the mean current, x the distance, either vertical or horizontal, between the points of observation, and when the current speed is required to appear as v^2. The author shows that, with $\alpha = 6 \times 10^{-12}$, this equation gives estimates of A of the correct order of magnitude, in conditions so diverse that x varies from $2{\cdot}2 \times 10^3$ cm. for vertical separations in Long Island Sound to 10^8 cm. for horizontal separations in the deep water of the Atlantic Ocean, while v varies from 0·25 cm./sec., as found by dynamical computation for the Atlantic deep water, to 100 cm./sec. for tidal currents at Georges Bank.

Riley's data indicate that the lateral eddy diffusivity is increased in stable water, as postulated by Parr, and he gives a modified equation for these conditions, also dimensionally correct, which includes a stability term. The vertical coefficients of eddy diffusion and conduction are much reduced in stable water and the author finds that they are approximately proportional to $v(gE)^{-\frac{1}{2}}$, where E is the stability, although this empirical result cannot be reconciled in any simple way with the dimensional considerations.

Owing to the present lack of knowledge of the mechanism of turbulent mixing in the sea and the comparative paucity of data, particularly on lateral mixing, one can hardly expect finality in any proposed formulae. Riley's investigation is to be welcomed as providing working hypotheses which may stimulate further work on this subject.

K. F. B.

F. C. Fuglister. "Annual Variations in Current Speeds in the Gulf Stream System." Journ. Mar. Res., **10**, 1, pp. 119—27, 6 figs. New Haven, Conn., 1951.

In this paper the author has calculated monthly resultant current speeds for ten areas of the western part of the main circulation eddy of the North Atlantic. Of these, four are in the Gulf Stream proper and one is in its extension, the North Atlantic Current. The remainder are as follows:— south-west of the Azores, the Trade Wind region (Long. 55°W.), the Guiana Current, the Caribbean Sea, and the region of the Bahamas.

Marked annual variations of current speeds are found in the Trade Wind areas, and also in the Caribbean Sea and in the Florida Current section of the Gulf Stream. In the other areas the seasonal variation, though it exists, is not so definite. It is interesting to note, however, that in each of the regions selected the time of minimum strength is in the autumn; in the main stream from the Caribbean Sea to south of Cape Hatteras, the period of minimum is exactly the same, October to November.

From the Trade Wind region in longitude 55°W. to the Gulf Stream south of Cape Hatteras the maximum speed is in summer; north-east of this cape it is in April to June. The greatest seasonal variation of strength is in the Florida Current, where the summer maximum speed of about 66 miles per day falls to about 49 miles per day in October.

The monthly resultants of speed have been analysed harmonically and the author shows that a fair approximation to the plotted curves can be obtained by combining the first two harmonic terms, the annual and semi-annual periods. In the southern and eastern areas of the Atlantic eddy, the amplitudes of these terms are nearly equal; in the other areas the annual period has the greater amplitude.

Comparisons are made between the computed variation of the Florida Current and the readings of the Miami tide gauge, and also between the Gulf Stream south of Cape Hatteras and the Charleston gauge; agreement is closest in the second half of the year, when the current strength falls to the minimum.

The variations of speed are also compared with the wind components in the direction of the current, for some of the areas. As would be expected, the wind and current fluctuations are approximately the same in the Trade Wind and Caribbean areas. In the North Atlantic Current area, however, only a very partial resemblance is found. The source of the wind data, referred to by the author as the British Admiralty charts of the North Atlantic, is presumably the *Monthly Meteorological Charts* of the Atlantic Ocean, which with similar charts for other oceans were computed in the Marine Branch of the Meteorological Office.

The seasonal variation of surface currents, to which Fuglister's work is a valuable contribution, is a very interesting subject, and the increasing accumulation of data for all oceans opens up many possibilities for its more accurate investigation. One difficulty, which the author points out, is that in calculating a vector mean, each observed current has to be taken as the current at the position midway between the beginning and end of the ship's run. As the periods for which currents are calculated may be anything up to 24 hours, the method frequently integrates a number of changes of the main current in speed and direction and may also integrate a main current with possible countercurrents or eddies.

The speed of a vector mean current for a given area is dependent not only on the speeds of the individual currents but also on their directions, since the

greater the divergence of their directions from the vector mean direction the lower will be the vector mean speed. The author has minimized this difficulty by choosing areas where the divergences of current direction throughout the year are not great, but as no oceanic area exists without some degree of divergence of individual current directions, the results must to some extent represent the annual variation of the vector mean speeds rather than that of current speeds.

In addition to the work of computing vector means of current, current roses, and predominant currents for the construction of current atlases the Marine Branch of the Meteorological Office has done a considerable amount of work in the determination of the annual variation of vector mean speeds and directions. In the cases of the Caribbean and of the Gulf Stream south of Cape Hatteras the curves of speed variation are in general agreement with those derived by F u g l i s t e r; most of his other areas are not the same as those chosen in the Marine Branch, which are in general more extensive.

Where the currents run due west, or very nearly so, as in the case of the Equatorial Currents of all oceans, the method adopted in the Marine Branch was to compute for each month the difference of the west and east components of the currents. In all oceans these annual curves show two maxima, the times of which differ in the different oceans and, in the case of the South Equatorial Current of the Pacific, in different longitudes of the same ocean. The further investigation and elucidation of this result will constitute an interesting problem in current variation.

E. W. Barlow.

L. B. Holthuis. "The Caridean Crustacea of Tropical West Africa." Atlantide Report No. 2, pp. 7—187, 34 figs. Copenhagen, 1951.

There is as yet no comprehensive work on the decapod crustacea of West Africa and anyone who has occasion to determine material from that region must refer to numerous papers in many scientific journals. Dr. H o l t h u i s, who already has to his credit a number of important publications on the Caridea, must have felt the need for such a work while studying the shrimps and prawns collected by the Danish "Atlantide" Expedition. In this report he includes all the marine and freshwater species of Caridea hitherto recorded from Tropical West Africa from Cape Blanco (15°N.) to Great Fish Bay, Angola (17°S.). These total 112 species of which the "Atlantide", which was not concerned with the freshwater fauna to any appreciable extent, obtained 60. Species not represented in the "Atlantide" material appear in smaller type and are not described, though adequate references and the known distribution of each are given. Of the 60 species collected by the "Atlantide" no less than 31, of which 15 are described as new, are here recorded for the first time from West Africa.

The collection was especially rich in littoral species. Many of these occur in the Mediterranean or further north; they tend to fade out somewhere between the Cape Verde Islands and Sierra Leone and are generally small or stunted in the warmer part of their range where conditions are not optimal. A few species range as far south as the Congo or Angola, and an occasional one may reach the Cape. Several species are common to Tropical West Africa and the Atlantic coast of Central America.

The freshwater fauna also includes a number of species which are identical with, or very closely related to, ones from Central America (e. g., species of

Atya and *Macrobrachium,* better known as *Palaemon).* The genus *Caridina,* on the other hand, does not occur in the New World but is widely distributed throughout Africa and the Indo-Pacific. The only known freshwater species of the marine family Alpheidae occur in West Africa. Now, rather surprisingly, the "Atlantide" obtained young specimens of a species of *Atya* at three marine stations, off Liberia, the Cameroons, and the Belgian Congo respectively. Two previous marine records of this freshwater genus appear to have been due to errors in labelling the specimens, but H o l t h u i s mentions an authentic unpublished record from Florida (p. 23).

Dr. H o l t h u i s has produced a careful and competent systematic report, accompanied where necessary by very good figures. But, as he points out, certain families of the Caridea are badly in need of critical revision. For example, *Processa canaliculata* Leach has long been considered a cosmopolitan species and the literature includes a number of West African records. Yet the rich "Atlantide" material of the genus belonged to three new species while the true *P. canaliculata* was absent. The earlier records would therefore appear to be erroneous and the material assigned to *P. canaliculata* in museum collections in need of revision. The European species of the genus *Hippolyte* are still insufficiently known. Various changes in nomenclature recently introduced by Dr. H o l t h u i s may puzzle the beginner and even the specialist may take time to get accustomed to them. For example, "*Spirontocaris cranchii* (Leach)" is now known to include two distinct species which he calls *Thoralus cranchii* (Leach) and *Eualus occultus* (Lebour). The occurrence of a species of *Bythocaris* off Sierra Leone and so far south of the known range of the genus is unexpected.

In the absence of an index, a short table of contents comprising the families, with page reference to each, would have been useful.

I. Gordon.

D. M. Reid. "Report on the Amphipoda (Gammaridea and Caprellidae) of the Coast of Tropical West Africa." Atlantide Report No. 2, pp. 189—291, 58 figs. Copenhagen, 1951.

The Gammaridea present exceptional difficulties to the systematist not only because they are so numerous but also because marked changes may occur in form as well as in size after the individuals have reached sexual maturity. To further complicate matters, intersexes of different kinds may occur. For example, in a species of *Allorchestes* the juvenile specimens possess the heavy gnathopods II of the male as well as rudimentary brood-plates. In the genus *Ampelisca* the intersex form is that of a female without brood-plates but with certain male characteristics such as copulatory hooks. Under laboratory conditions, a male intersex of *Jassa* possessing fully formed brood-plates mated with a normal female of the same brood (see S e x t o n & R e i d, 1951, *J. Linn. Soc. Zool.* xlii, p. 44). As nothing is known about the genetical constitution of these intersexes, and hardly any breeding experiments have been undertaken, the author has not been able to discuss them at length (pp. 191—192).

No two specialists would agree as to the exact number of species represented in the rich "Atlantide" material. Twenty-four families af Gammaridea are represented by over a hundred species, 48 of which are here recorded for the first time from Tropical West Africa. These include 28 new species or varieties; for the most part the author calls them species, but in one section of the Ampeliscidae he follows S c h e l l e n b e r g in regarding them as varieties of known species. In no instance is the whole animal figured, but only such

parts as are deemed essential for specific determination. This conforms to present-day practice and probably does not inconvenience the specialist, but others must refer to older works like S a r s' s "Crustacea of Norway" volume to discover what the members of a given family or genus look like. There is a slight error in the legend to Figure 22, page 223, where the mouth parts have been transposed; *h, i, j,* are respectively mandible, maxilla 1, and maxilla 2.

The systematic part is followed by a list of the species found at each station and then the species are arranged according to the habitats in which they occur. The family Caprellidae, which comprises a very small percentage of the whole collection but includes one new species, follows. Finally, in an appendix are listed all the species hitherto recorded from the West African coast between Gibraltar and Lüderitzbay (36°N. to about 27°S.). For convenience this long coastline has been subdivided into seven regions and the distribution of each of the 206 species is tabulated according to these.

I. Gordon.

Th. Mortensen. "Report on the Echinoidea collected by the 'Atlantide' Expedition." Atlantide Report No. 2, pp. 293—301, 1 fig., 2 pl. Copenhagen, 1951.

The collection of Echinoidea is small compared to either of the Crustacea collections reviewed above. It has been determined by the foremost authority on Echinodermata of our times, Dr. T h. M o r t e n s e n, whose death at the age of 84 occurred recently. The "Atlantide" material is of interest mainly from a zoogeographical point of view. It comprises 18 species of which one is new but closely related to a West Indian species and another has hitherto been recorded only from the Barbados. This emphasizes once again the close relationship between the faunas on both sides of the Tropical Atlantic Ocean. Like the majority of the Caridea, the Echinoidea have pelagic larvae, but the percentage of identical, or closely related, species on both sides of the Atlantic is much higher in the latter than in the former. Dr. M o r t e n s e n mentions the absence of several species known to occur in Tropical West Africa, adding that much remains still to be done, especially off the Cape Verde Islands, before our knowledge of the Echinoid fauna is reasonably complete.

I. Gordon.

H. Blegvad. "Fluctuations in the Amounts of Food Animals of the Bottom of the Limfjord in 1928—1950." Rep. Danish Biol. Stat., No. 53, pp. 3—16, 4 figs. Copenhagen, 1951.

E. M. Poulsen. "Changes in the Frequency of Larger Bottom Invertebrates in the Limfjord in 1927—1950." Ibid, pp. 17—35, 4 figs. Copenhagen, 1951.

The bottom fauna studies carried out in the Limfjord by the Danish Biological Station are well known to all Marine biologists. Quantitative samples with the 0·1 sq. m. Petersen grab have been collected more or less regularly every spring and autumn since 1909, and the eel-seine has been used since 1927 to obtain annual samples of the larger invertebrates.

In a previous paper Dr. B l e g v a d described the work of the years 1918—1927, and the first of the above papers contains his account of the material collected during the period 1928 to 1950. The data are presented in the same way as in the previous paper, and the reader may thus follow

the general trends over a fairly long period. The figures show that, in comparison with previous years, only slight changes took place in the quantities of food animals in the Limfjord from 1928 to 1950, and that the weights (except for high values in 1929—30 due to large numbers of *Abra alba* and *Pectinaria koreni*) were much lower than in the period 1909—27. The values seem to indicate a continuation of the downward trend previously noted as beginning about 1923.

As before, Dr. Blegvad seeks to account for the decrease in the amount of food animals. He notes the disappearance of eel-grass (*Zostera marina*) in 1933, but considers that this does not explain the decline in bottom fauna. He recalls his previous work on the viviparous blenny (*Zoarces viviparus*) the predations of which must remove a not inconsiderable quantity of bottom fauna annually, and shows that stocks of the blenny were comparatively large. Nevertheless it cannot be concluded definitely that this fish represents a main factor controlling the quantity of invertebrates. There does appear, however, to be some correlation between the very severe winters during 1939—1942 and the poor spring samples of 1940, 1941, and 1942. This conclusion, that "exceptionally anomalous conditions of temperature greatly influence the appearance of food animals" is undoubtedly valid. Dr. Blegvad refers finally to the detrimental effect on the bottom fauna of the trawl gear which is being used increasingly in the Limfjord. His personal observations made while actually on the sea bottom in diving dress are of great interest.

In the second paper listed above, Dr. Poulsen describes for the years 1927—1950 the annual fluctuations of the larger bottom invertebrates in the Limfjord as shown by eel-seine catches and, in the case of marketable species, by fishery statistics.

He lists 17 species of larger invertebrates which are more or less common in the Limfjord, and notes factors — salinity, nature of bottom, and predation — which influence their distribution. There are considerable annual variations in the numbers of the organisms, and he attempts to account for these. A considerable part of the fluctuation is probably due to the inefficiency of the gear as a quantitative sampling instrument, particularly when dealing with organisms which occur in small numbers. However, the influence of other factors is suggested — for example, nine of the species studied seem to be adversely affected by the cold winters of 1939—1942. Considering the animals of commercial importance, Dr. Poulsen suggests that the decline in the yield of lobsters is due entirely to overfishing, and that this factor also operates in the case of the prawn fishery. Prawns, however, seem to be more affected by natural conditions such as the severe winters and the disappearance of Zostera, although the latter phenomenon seems to have had no general effect in the Limfjord.

The author concludes by pointing out that the Limfjord cannot support further intensification of the established fisheries. He recommends the development of new fisheries, such as the recently initiated fishery for *Asterias rubens*, the importance of which he comments on.

The general impression formed from the above papers is that as yet no clear-cut answer can be given to Dr. Blegvad's own question, "What is the cause of this marked decrease in the amount of food animals?" However the suggestions put forward are undoubtedly of great value. The problem, involving as it does so many variable factors, is a very complex one, and it seems certain that the solution will eventually be reached only by studies of the above type which bring together continuous collections of data from long periods of years.

A. D. McI.

D. B. DeLury. "On the planning of experiments for the estimation of fish populations." Journ. Fish. Res. Bd. Canada, **8**, 4, pp. 281—307. Toronto, 1951.

P. H. Leslie and D. Chitty. "The estimation of population parameters from data obtained by means of the capture-recapture method. I. The maximum likelihood equations for estimating the death rate." Biometrika, **38**, pp. 269—292. London 1951.

N. T. J. Bailey. "On estimating the size of mobile populations from recapture data." Biometrika, **38**, pp. 293—306. London 1951.

P. A. P. Moran. "A mathematical theory of animal trapping." Biometrika, **38**, 3+4, pp. 307—311. London, 1951.

Among the most important factors to be determined in the population study of a commercial fishery, especially if any regulation is to be applied, are the total abundance, and particularly the mortality rates due to fishing and natural causes. The evaluation of these parameters is a fruitful field for collaboration between biologist and statistician, which has too often been neglected. These papers have developed proper statistical techniques for some simple cases. The methods given (of mortality rates and total population) yield results of known sampling variance; for the methods based on maximum likelihood theory these variances are as small as possible. Also, if a general idea of the magnitude of the parameters is known, then it is possible to determine the amount of marking to be done for any desired accuracy, as is shown by DeLury.

Though only DeLury deals explicitly with fish populations, the type of population envisaged is similar in all the papers; that is, a simple closed one with no emigration or immigration, and in which the animals, both marked and unmarked, are distributed randomly. They also assume that the marks do not affect the animals in any way, such as injuring them, thus causing high initial losses directly after marking, or an increased steady death rate; that the marks are not liable to be detached from living animals; and that marked and unmarked fish are equally liable to capture.

Moran and DeLury have used methods, independent of marking, by which the decrease in catch with time is related to the numbers of fish already caught. DeLury develops two expressions, which when plotted yield straight lines, which can be fitted by the usual regression methods. The second of these (equation 2.3) is essentially the same as the usual method of analysing the abundance of successive year-classes to get mortality rates. By applying these methods to marked and unmarked fish separately, a check can be made on some of the basic assumptions, e. g., that marked and unmarked fish are equally vulnerable to fishing. An outline is also given for two types of mortality, e. g., fishing and natural deaths, operating simultaneously.

Leslie and Chitty deduce maximum likelihood estimates of the death rate for marking experiments where an animal may carry any number of marks or a numbered tag. Animals are captured at successive times, marked and released, a note being made of all marks carried by the animals, when caught. They also discuss methods of grouping the data for easier handling, and the loss of information in so doing — zero for their method B. DeLury obtains for fishes that do not carry a numbered tag but can be only either marked or not marked (e. g., marked by mutilation), a maximum likelihood estimate for the whole population. This is applied both to the Petersen and Schnabel types of experiment. By comparing the results of these two

types, of which only the former is not distorted by natural mortality, an expression is obtained for the mortality due to causes other than fishing; though the variance attached to it is not stated, it is probably large. Bailey gives a more strictly mathematical outline of various marking methods, of which the most important is the trellis diagram, from which total population and both birth and death rates can be determined.

It should be stressed that these papers do not claim to be directly applicable to marine fishes. They have been developed with reference to small mammals and insects, or fish in small lakes, and for these the assumptions made may be justifiable. For most marine fishes, however, the deviations from the assumptions are likely to be so great as to make models based on them of little direct value. For instance, it is probable that English plaice marks wear off at the rate of some 15 % per year, while there are very heavy initial losses in marking many marine fishes. Statistical ideals may, at present, have to be sacrificed to biological fidelity, and a model used which, though giving an estimate subject to considerable sampling variation, does take into account as many as possible of the biological complications. For example, Beverton and Holt in a forthcoming paper have developed deterministic models to account for initial deaths on marking, and losses due to marks wearing off. It remains for the future to develop the best statistical methods for these cases.

The real importance of these papers to fisheries biologists lies not so much in their immediate practical application, but in the advances they make towards the provision of a sound statistical theory for the rather complex situations occurring in marking experiments on most marine fishes.

J. A. Gulland.

Jørgen Knudsen. "Contributions to the Biology of the Whiting (*Gadus merlangus* L.) in the Danish Waters." Rep. Danish Biol. Stat., No. 52, pp. 27—40, 5 figs. Copenhagen, 1950.

The publication of this paper draws attention to the scarcity of literature giving a detailed account of the biology of the whiting. A considerable knowledge of this species has doubtless been acquired in the course of general fishery research in different countries but so far little of this has been made available for other research workers. The appearance of this account of the whiting in Danish waters must, therefore, be welcomed by all who are interested in the species.

The author stresses the limitations of the material with which he has worked, but presents a lucid account of his investigations. The Kattegat, Belt Sea, and outer Baltic are essentially nursery areas for the young whiting, most of which penetrate these areas after a larval life spent possibly in the southern North Sea or Skagerak. Between two and three years of age, with the approach of first maturity, the whiting depart from the nursery grounds. Small numbers of older fish remain on the grounds; these are regarded by the author as having not yet reached the mature stage. Further information on this point, however, might have been provided by a statement on the condition of the reproductive organs. Growth is considered to be slower than in Icelandic and French waters but the standards for comparison can scarcely be regarded as suitable. Within the area of the investigations the growth of the 0-group fish varies from year to year, which is not altogether surprising if consideration is given to the possible differences in the time and place of spawning, the distance drifted by the eggs and larvae, and the distance travelled by the young fish before reaching their final feeding grounds. The

density of the whiting population diminishes in proceeding from the Kattegat to the Baltic, but overall, the stocks have increased during the period 1927—1938. This is attributed to a rise in the salinity of the Kattegat and Belt Sea in the same period. This paper is a useful contribution to the biology of the whiting and it is to be hoped that others will follow, to give a complete picture of the species within the North Sea and elsewhere.

B. B. R.

G. Ehnholm. "Studier över strömmingen i Östra Kvarken." Akademisk Avhandling, Helsingfors Universitet, pp. 1—94, 21 figs., 1 pl. Helsingfors, 1951.

The northern part of the Baltic, the Gulf of Bothnia, consists of two parts, the Bothnian Sea and the Bothnian Bay, which are connected with one another by the wide, shallow sound called Kvarken. On both the Swedish and the Finnish sides of this sound there are rather extensive archipelagos and it is in the archipelago on the Finnish side and the adjacent parts of the open sea that Ehnholm has carried out his investigations. In this rather limited area he has undertaken a very close and detailed study of the morphology and biology of the herring and has obtained quite good and interesting results. These investigations confirm several facts already known about the herring in other parts of the Baltic and many new facts have been brought to light.

Because of its cold climate and brackish water the Gulf of Bothnia offers very extreme conditions. It is therefore strong evidence of the herring's astounding adaptability to different kinds of milieu that it is numerous enough to support a fairly extensive fishery in this area.

As in most other parts of the Baltic, spawning herring occur in the Kvarken from spring till autumn. Ehnholm has shown that in spite of this very prolonged spawning period, the hydrographical conditions under which the different shoals or spawning communities spawn are fairly uniform, owing to the successive displacement of the spawning locality during that time from the inner, shallow, and more or less enclosed parts of the archipelagos through the middle and outer parts of the archipelagos to the banks in the open sea outside.

The herring in this area seem to spawn preferably in temperatures of 8°—14°C., with the salinity as low as possible for the locality. Their spawning migrations are therefore directed towards localities with low water densities.

These hydrographical conditions are to be met with in spring in the inner parts of the archipelagos, in summer in the outer parts of the archipelagos, and in late summer or autumn on the banks outside the archipelagos.

The author distinguishes four different spawning communities in this area, of which three are migratory and one seems to be stationary.

I. Principal spawning period, May—June; spawning ground, the innermost shallows of the archipelagos; number of vertebrae, $53{\cdot}34 \pm 0{\cdot}15$ (Ford).

II. Principal spawning period, end of May to beginning of July; spawning ground, the outer parts of the archipelagos; number of vertebrae, $54{\cdot}45 \pm 0{\cdot}09$ (Ford).

III. Principal spawning period, July; spawning ground, the outer parts of the archipelagos; number of vertebrae, $54{\cdot}45 \pm 0{\cdot}08$ (Ford).

IV. Principal spawning period, the autumn, from the latter part of August; spawning ground, banks outside the archipelagos; number of vertebrae, $54{\cdot}55 \pm 0{\cdot}12$ (Ford).

Groups I, II, and IV are migratory, whereas III seems to remain in the archipelagos. This "race", which is of inferior economic value, also seems

to prefer a somewhat higher (>14°C.) temperature for its spawning than the others.

When stating the number of vertebrae, the author follows F o r d' s method, which gives a number one vertebra less than when they are counted by the methods mostly used by herring specialists. The "races" II, III, and IV have a vertebral number which is about the same as that found in other parts of the Baltic. The corresponding number for race I is, as E h n h o l m points out, exceedingly low and corresponds very closely to the vertebral number of herring from the White Sea, as described by A v e r i n z e v.

In Kvarken, as in many other regions, there is a marked correlation between the number of vertebrae and the salinity on the spawning grounds; those herring spawning in the innermost parts of the archipelagos, where salinity amounts to only about 3·5 ‰, have a vertebral number of only 53·34 (F o r d), whereas the corresponding number for the herring spawning on the banks outside the archipelagos in a salinity of 4 to 5 ‰ is 54·55 (F o r d).

Beside the facts briefly related here, E h n h o l m' s paper contains much valuable information about growth-rate, development of the fry, food and feeding habits, etc., and also some notes on the fishery.

Chr. Hessle.

J. W. Jones. "Salmon studies 1950." Min. Agric. Fish., Fish. Invest., Ser. 1, **5**, 5, pp. 1—11. London, 1951.

This paper by Dr. J o n e s deals with the salmon of the Cumberland Derwent and the Cheshire Dee. Just over five hundred sets of scales of salmon from the Cumberland Derwent were examined. Three smolt classes were recorded, 95·8 % of all fish being of the two-year smolt class, the one-year smolts being less important than the three-year smolts. Only 5·6% of the fish were "spring fish", the remainder being summer fish. Incidentally figures in the text on page 3 differ from those in Table 2; the latter appear to be correct. Dr. J o n e s mentions on page 6 that "the small 'spring' fish and large 'spring' fish taken in late August showed no erosion of the scale edge". A similar condition was found in the "spring" fish in the two following months. These fish are intriguing for there is no doubt that they are not spring fish in the ordinary sence of the term but belated grilse or small summer fish. In the summary on page 6 the statement under (2) is certainly incorrect, the terms "spring" and "summer" being transposed, whether by the author or the printer is not obvious.

Five hundred and seventy-three sets of salmon scales from the Cheshire Dee, a river on which Dr. J o n e s has worked for many years, were examined. By a coincidence the smolt classes were identical with those from the Cumberland Derwent. Spring fish were more plentiful than summer fish, large spring fish comprising just over sixty per cent. of the total. The material on which this investigation is based was taken from salmon running in the open fishing season, but it is obvious that there are considerable runs of fish before the fishing season opens. Although only a minor matter the author is inclined to "round off" percentages in the text, but he is not always consistent, as can be seen when figures on pages 7 and 8 are compared.

This paper adds much to our knowledge of the salmon in Great Britain and indicates the great diversity of salmon in its different environments. For example, Dr. J o n e s gives the average weights of the different age-groups of the salmon of the Cumberland Derwent, which differ considerably from those of Irish rivers only just on the opposite side of the Irish Sea.

A. E. J. W.

C. B. Rees. "The Identification and Classification of Lamellibranch Larvae." Hull Bull. Mar. Ecology, **3**, 19, pp. 73—104, 4 figs., 5 pl. Hull, 1950.

The identification of lamellibranch larvae has proceeded more slowly than the identification of the planktonic larvae of most other marine invertebrates. During the last decades several bivalve larvae have been described and identified, especially from the waters around Canada, Japan, and northern Europe. However, the descriptions were often ambiguous because too little was known about which characters are and which are not peculiar to the species. Therefore, the description of a larva of one species often also fits other species.

Rees's paper offers the first systematic classification of lamellibranch larvae based on preserved material from the North Sea. The characters used in the classification are hinge structures, as well as shape and texture of the shells of the larvae. The position of the hinge, i.e., anterior or posterior, the position of the ligament, and the development, position, and shape of the teeth and flanges offer sufficient characterization to refer all larvae from the plankton samples to 18 basic types. The resulting classification closely resembles the classification of the adults.

The 18 types comprise all groups of North Sea lamellibranchs except Nuculacea, Isocardiacea, and Gastrochaenacea. Most of the types are characteristic of only one super-family. However, three pairs of families, viz., Pectinacea and Anomiacea, Pteriacea and Ostreacea, and Saxicavacea and Myidae, have common types.

The basic types generally are well separated, which makes it fairly easy to find the group to which an unknown lamellibranch larva belongs, provided the larva is old enough for the characteristic structures in the hinge to be developed. Assignment to genus or species is attempted by means of shape and texture of the valves.

Rees describes 77 types of North Sea lamellibranch larvae. Of these about 30 are identified to the species. The species is uncertain for about 20 of the types, whereas specific names cannot be suggested for the rest.

Instead of detailed descriptions, microphotographs of all the types are given. Actually most descriptions are very short. Unrecognized larvae must therefore be identified mainly by means of the photographs, after the hinge type has been determined.

C. B. J.

M. N. Mistakidis. "Quantitative studies of the bottom fauna of Essex oyster grounds." Min. Agric. Fish., Fish. Invest., Ser. 2, **17**, 6, pp. 1—47, 9 figs. London, 1951.

Early in 1947 the British Ministry of Agriculture and Fisheries established a Shellfish Research Station at Burnham-on-Crouch, Essex. This was not only to elucidate the causes of the catastrophical decline of the east coast oyster industry, but also to try to establish conditions necessary for a revival and restoration of these formerly important oyster grounds. This paper is the first scientific report resulting from the scheme. In the winter of 1948—49 the author carried out a quantitative survey of the bottom fauna of three uncultivated and semi-derelict oyster layings, one in the river Crouch, and two adjoining layings in the river Roach. It is planned to repeat the survey in about five years time, when it is expected that the grounds will be fully restored and restocked with oysters. There is every reason to expect

changes in biological conditions on the bottom through the measures to be taken, and it is therefore anticipated that changes in the composition of the bottom fauna will reflect the degree of restoration of the now semi-derelict layings.

Although hydrographical conditions prevailing on all three selected layings can be considered as fully marine, striking differences appeared to exist in their respective bottom faunas. Neither of the layings was found to be uniformly settled. On the contrary, considerable differences in the composition of the bottom fauna occurred from station to station. Though the nature of the bottom deposits governs largely the character of the bottom fauna, evidence could be adduced that also other factors — e. g., the quantity of suspended silt in the water — are of considerable influence. Sponges and Ascidians appeared to be rare in waters carrying much suspended silt. It is explained that this inorganic silt may prevent the effective functioning of the feeding mechanism of sponges and Ascidians. This may be true, but it is not made clear why other filter feeders (e. g., *Crepidula* and *Ostrea*) do not seem to suffer noticeably from such conditions. I wonder whether smothering of the young sessile phases is not a factor worth studying in silt-laden waters.

Another salient point is that the composition of the bottom fauna of the Essex oyster beds resembles qualitatively in many respects those of the oyster beds in the Oosterschelde (Holland) and in the German Wattensee. This is the more striking, as the Essex oyster beds are completely overrun by two most unwelcome intruders, *Crepidula fornicata* and *Elminius modestus*. The similarity in bottom fauna indicates that notwithstanding this invasion and the semi-derelict state of the layings, general biological conditions are still those appealing to *Ostrea edulis*, once found in large numbers in these places.

It is expected that the culture methods to be taken will ultimately deprive *Crepidula* of its dominating position, and will also serve to remove most of the soft black mud deposited by *Crepidula* in recent years. It is feared, on the other hand, that *Urosalpinx cinerea*, the American Atlantic oyster drill, will increase in numbers where the bottom is cleaned and hardened. The author remarks very rightly that cleaning of fairly small plots does not reduce materially the population of *Crepidula* in the rivers, so that it cannot be hoped that settlement of young *Crepidula* will not occur on the cultivated layings. Shells scattered as cultch may soon be covered with slipper limpets under such conditions. Experience in Holland has shown that the harder and the more resistent the shells used, the greater the chance that *Crepidula* will soon overrun the carefully cleaned plots anew. Calculations of the increase of *Crepidula* populations are based on the assumption that only one new limpet per year will add itself to the chains. I am afraid that this is a little too optimistic, for shells scattered in the Oosterschelde may bear chains of 2 and 3 limpets within 6 months. It is our experience in Holland that on beds where a heavy settlement of *Crepidula* occurs regularly, only repeated chemical control of *Crepidula* (after dredging up all cultch) may give the young oysters a fair chance to dominate the picture continuously.

It seems reasonable to expect with M i s t a k i d i s that removal of large quantities of *Crepidula* will result in an increase in the available food supply of all the remaining bottom filter feeders, including oysters. Peculiarly enough, experience gained in Holland is not very clear in this respect. Dredging away of enormous quantities of limpets did not affect noticeably the growth and fattening of oysters, and occasionally quite fat oysters are found in the midst of *Crepidula* beds.

The author refrains from designating his animal groups as "communities",

which is a praiseworthy modesty. This is not only because of the "unnatural" domination by the foreign species *Crepidula* and *Elminius,* but also because such a system would wrongly give the general reader the impression that a well balanced combination of species occurs over vast areas, whereas in reality great differences are to be observed from place to place, differences which are not always easily explained in terms of bottom conditions and hydrographical climate. Moreover as "annuals" make up a rather high percentage of the bottom fauna, and as reproduction and settling are often very capricious, for reasons which are only partly understood, the quantitative relations will not only vary greatly from place to place, but also from year to year. It would therefore be precocious to give every local and temporary aspect of the bottom fauna of the oyster beds a consequential name.

P. Korringa.

G. R. Forster. "The biology of the common prawn *Leander serratus* Pennant." Journ. Mar. Biol. Assoc., N. S., **30**, 2, pp. 333—360, 14 figs. Cambridge, 1951.

Ce travail porte surtout sur la croissance et la reproduction et accessoirement sur la répartition et les migrations de l'espèce.

Les récoltes ont été effectuées d'Octobre 1949 à Octobre 1950, avec 3 types d'engins: chalut à crevettes, filets à main, casiers.

La croissance a été suivie par la technique des mensurations; en raison de la longue durée de la ponte et des différences d'habitat entre les groupes de tailles variées, le calcul de la croissance n'est qu'approximatif.

La métamorphose se produit en Juillet, apparemment dans les couches d'eau peu profondes. La taille moyenne des jeunes de l'année est de 5 cm. en Octobre. Puis la croissance s'arrête en hiver jusqu'en Juin. Au cours du 2ème été, les femelles grandissent plus vite que les mâles: en Octobre, elles mesurent 9 cm. et les mâles 7·5 cm. Au cours du 3ème été, la mortalité naturelle est très élevée, il ne reste que quelques rares survivants à l'automne. En effet, la comparaison des captures aux casiers en Mai et Juin indique une diminution dans la proportion des crevettes de plus de 10 cm. de long, le pourcentage des individus mesurant plus de 10 cm. tombe de 37 en Mai, à 10 seulement en Juin.

Ainsi l'espèce ne dépasserait pas l'âge de 3 ans, compte-tenu des très grandes crevettes prises parfois au chalut durant l'hiver, qui sont âgées vraisemblablement de deux ans et demi et plus.

Un auteur français (S o l l a u d) avait déjà signalé l'arrêt de croissance durant l'hiver et la croissance plus rapide des femelles. Il estimait la longévité des femelles à 5 ou 6 ans.

La première maturité sexuelle est précoce chez les mâles: des jeunes mâles nés dans l'année même, âgés de 6 à 7 mois, mesurant 4 à 4·4 cm. mis dans un aquarium avec une femelle à maturité l'ont fécondée car elle devint graînée. On trouve des adultes en Décembre parmi les plus petits mâles et des adultes en Mars parmi les plus petites femelles, âgés les uns et les autres de moins d'un an.

Les femelles sont graînées depuis Novembre jusqu'en Juin; l'époque de la ponte est de plus en plus précoce à mesure que la femelle grandit: elle a lieu dès Novembre pour les plus grosses crevettes, en Février—Mars pour les plus petites. Les oeufs restent attachés à la mère environ 4 mois à une température de 9 à 11°C.; il en découle que les éclosions se font principalement d'Avril à Juin.

Cependant, l'auteur a observé des grosses crevettes en Février, qui, d'après la maturation de leurs ovaires, se préparaient à une seconde ponte dans la saison. Quelques unes, parmi les plus grosses crevettes, pourraient se livrer à trois pontes par an, ce qui explique la présence de stades larvaires signalés par L e b o u r jusqu'en Septembre et Octobre.

Le nombre des oeufs produit par une femelle augmente avec la taille de la mère dans une proportion logarithmique: ainsi une crevette produit à 6 cm., 1,500 oeufs; à 7 cm., 1,600; à 10 cm., 3,500; à 10·5 cm., 4,200 oeufs.

L'examen des contenus stomacaux montre que l'espèce est omnivore et se nourrit surtout d'algues et de petits crustacés.

Les crevettes peuvent apercevoir des mouvements brusques, mais la vue, malgré la dimension des yeux, leur est d'un faible usage. Elles ne peuvent, sans l'aide des antennes, éviter les obstacles, localiser la nourriture, ou trouver une compagne, dans le cas des mâles.

Des migrations de faible amplitude sont provoquées par les marées et la lumière du jour. Ainsi la nuit les crevettes s'approchent du rivage. Les crevettes de la zone profonde des laminaires ne se font prendre que la nuit, au casier; le jour elles restent probablement cachées à l'abri des prédateurs — poissons et céphalopodes. Au contraire les crevettes à la côte sont attirées de jour par l'appât.

L'hiver il y a une migration générale vers le large, et retour vers la côte au printemps, vers Avril—Mai.

Les crevettes sont pêchées au chalut en hiver par 7 à 10 m. de profondeur, sur fond de vase, et les plus grosses, qui hivernent pour la seconde fois, par 18 à 30 m. Les pêcheurs de homards capturent de ces grosses crevettes de Novembre à Mars entre Berry Head et Start Point.

Cette étude, fort intéressante, mériterait d'être poursuivie. Les observations de l'Office Scientifique et Technique des Pêches Maritimes sur les côtes françaises de l'Atlantique semblent d'ailleurs confirmer les conclusions de M. F o r s t e r sur la reproduction et la croissance de l'espèce en Manche.

P. Desbrosses.

G. R. Forster. "Notes on *Leander squilla* L." Journ. Mar. Biol. Assoc., N. S., **30**, 2, pp. 361—367, 5 figs. Cambridge, 1951.

L'auteur a recherché les différences biologiques (croissance et migrations) pouvant apparaître par suite de la différence des climats entre la population de Plymouth et celle des côtes suédoises qui a été parfaitement étudiée par H ö g l u n d en 1943.

L'espèce *L. squilla* se tient dans des eaux plus superficielles que la précédente.

Durant l'hiver elle abandonne les estuaires, mais reste dans la région côtière, contrairement à son comportement dans les eaux suédoises où elle effectue une migration vers le large, fuyant vraisemblablement les eaux très froides (les eaux de surface sont, en Février, —1° à +1°C. à Kristineberg, tandis qu'elles sont de 7 à 8°C. à Plymouth).

Les mâles âgés de moins d'un an se tiennent plus au large que les femelles, semblant plus sensibles que celles-ci à la dessalure des eaux: comportement comparable à celui observé chez *Crangon vulgaris* par L l o y d and Y o n g e.

La ponte se produit vers la fin d'Avril et on trouve des femelles graînées jusqu'en Août; les oeufs restant attachés à la mère 6 semaines au plus (H ö g l u n d) il est possible qu'une même femelle ponde 3 fois par an.

Les stades post-larvaires commencent à apparaître à la côte en Août.

La croissance est plus rapide chez les femelles. Elle est continue dans la région de Plymouth, tandis que sur les côtes suédoises elle est arrêtée, l'hiver, ce qui s'explique par la différence des températures de surface entre l'une et l'autre régions.

Comme l'espèce précédente, celle-ci ne survit pas au 3ème hiver.

La croissance semble varier proportionellement à la température: par suite de températures de surface plus élevées en 1949 qu'en 1950, les tailles en Octobre étaient plus grandes pour des crevettes de même âge en 1949 que l'année suivante.

La nourriture est extrêmement variée, avec prédominance d'algues, et de nauplii de crustacés.

P. Desbrosses.

Current Bibliography.

Prepared by the Editor with the Assistance of Mr. A. C. Simpson.

NOTE. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given, but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

Subscribers and those on the distribution list will receive regularly upon application to the General Secretary copies of the Bibliography printed on one side of the page only, for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

---

1) General Oceanography.

1) a Expeditions.

Anon. "Ungava Bay Fisheries Expedition, 1947, 1948 and 1949". Polar Record, **6**, 41, pp. 92—5, Cambridge, 1951.

Fabre de la Ripelle, H. "Croisière du 'Bougainville' dans l'Océan Indien austral (11 janvier—3 mars 1939)". Ann. Hydrogr., 3e Sér., **19**, pp. 121—77, Paris, 1947.

1) b Institutes.

Barrett, J. H. "Council for the promotion of field studies. 3. Dale Fort field centre". Nature, **167**, 4255, pp. 801—2, London, 1950.

Zenkevich, L. Q. "Achievements and perspectives of development of Soviet hydrobiology, particularly for seabasins". Zool. Zhurn., **30**, 2, pp. 111—20, Moscow, 1951. (In Russian).

2) Hydrography.

2) a Apparatus and Methods

Cubillos, V. R. M. "Determinación de la salinidad por un método sencillo y rápido, especial para biologos". Rev. Biol. Marina, **1**, 3, pp. 236—7, Valparaiso, 1949.

Ishiguro, S. "An electrical recorder for sea-wave pressure". Oceanogr. Mag., **1**, 3, pp. 135—41, Tokyo, 1949.

Jacobsen, J. P., Robinson, R. J. & Thompson, T. G. "A review of the determination of dissolved oxygen in sea water by the Winkler method". Assoc. d'Océanogr., Union Géodés. Géophys. Internat., Publ. Sci., 11, Bergen, 1950.

Kalle, K. "Einige Vereinfachungen der Chlor-Titration für biologische und wasserbaukundliche Zwecke in Küstengewässern". Deutsch. Hydrogr. Zeitschr., **4**, 1/2, pp. 13—7, Hamburg, 1951.
Longard, J. R. "A calibrating instrument for simulating the temperature and pressure conditions in the sea". Nova Scotian Inst. Sci., 6th Ord. Meeting, Halifax, 1950.
Menaché, M. "Sur l'emploi de l'eau normale de Copenhague comme étalon dans le dosage de la chlorinité des eaux Méditerranéennes". Bull. Inst. Océanogr., 985, Monaco, 1951.
Moya, R. C. "Determinación del oxigeno en el agua de mar". Rev. Biol. Marina, **1**, 1, pp. 46—56, Valparaiso, 1948.
Schüler, F. "Über ein neues Anzeigeverfahren für Echolote". Deutsch. Hydrogr. Zeitschr., **4**, 1/2, pp. 52—7, Hamburg, 1951.

2) b Surveys.

Alander, H. "Baltic Area. Hydrography (Swedish observations)". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 157—8, Copenhague, 1950.
d'Albe, E. M. F. "Sur les embruns marins". Bull. Inst. Océanogr., 995, Monaco, 1951.
Anon. "Report on sea and weather observation on Antarctic whaling ground (1947—48) . . . (1948—49)." Oceanogr. Mag., **1**, 1, pp. 49—88; 3, pp. 142—73, Tokyo, 1949.
Anon. "International ice observation and ice patrol service in the North Atlantic Ocean. Season of 1950". Coast Guard Bull., 36, Washington, 1951.
Brattström, H. & Dahl, E. "On a new method of describing collecting stations in the Sund". Lunds Univ. Årsskr., N. F., Avd. 2, **42**, 17, pp. 1—13, Lund, 1946.
Faure, L. "Comparaison des températures de surface en Manche occidentale et dans l'Atlantique en 1949". Cons. Internat. Explor. Mer, Ann. Biol., **6**, p. 46, Copenhague, 1950.
Furnestin, J. "Hydrologie côtière du Maroc (Année 1948)". Cons. Internat. Explor. Mer, Ann. Biol., **6**, p. 46, Copenhague, 1950.
Granqvist, G. "Regular observations of temperature and salinity in the seas around Finland, July 1946—June 1950". Merentut. Julk., 150, Helsinki, 1951.
Granqvist, G. "Harmonic analysis of temperature and salinity in the sea off Finland and changes in salinity". ibid., 152, Helsinki, 1952.
Guyot, A. "L'hydrologie du canal de Sicile". Com. Cent. d'Océanogr. Etudes Côtes, Bull. d'Inform., 3. Ann., 7, pp. 269—80, Paris, 1951.
Jensen, A. J. C. "Environment. Hydrography (Danish observations)". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 156—7, Copenhague, 1950.
Kändler, R. "Der Einfluss der Wetterlage auf die Salzgehaltsschichtung im Übergangsgebiet zwischen Nord- und Ostsee". Deutsch. Hydrogr. Zeitschr., **4**, 4/6, pp. 150—60, Hamburg, 1951.
Kawamura, S., Tsubata, F. & others. "Report on sea and weather observations on Antarctic whaling ground (1949—1950)". Oceanogr. Mag., **2**, 4, pp. 149—80, Tokyo, 1950.
Ketchum, B. H. "Hydrographic factors involved in the dispersal of pollutants introduced into tidal waters". Journ. Boston Soc. Civil Engineers, **37**, pp. 296—314, Boston, 1950.
Lumby, J. R. "Mean monthly data of surface salinities and temperatures from the Hull—Hanstholm route for 1947, 1948 and 1949, and at Smith's Knoll, Galloper and Varne lightvessels 1946—49". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 114—5, Copenhague, 1950.
Segerstråle, S. G. "The recent increase in salinity off the coasts of Finland and its influence upon the fauna". Cons. Internat. Explor. Mer, Journ. du Cons., **17**, 2, pp. 103—10, Copenhague, 1951.
Tait, J. B. "Northern North Sea. Hydrography (Scottish investigations)". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 83—7, Copenhague, 1950.
Tauber, G. M. "Voyage in the Antarctic in 1947—48". Izvest. Obshch., **81**, 4, pp. 369—85, Leningrad, 1949. (In Russian).
Thomsen, H. "Southern North Sea. Hydrography." Cons. Internat. Explor. Mer, Ann. Biol., **6**, p. 114, Copenhague, 1950.
Thomsen, H. "Transition Area. Hydrography." ibid., **6**, p.143, Copenhague, 1950.
Thomsen, H. "Baltic Area. Hydrography." ibid., **6**, p. 156, Copenhague, 1950.
Trotti, L. "Prima crociera talassografica del 'Robusto' nel Mare Ligure ed Alto Tirreno". Cent. Talassogr. Tirreno, Pubbl. 7, Genova, 1950.
Trotti, L. "Ricerche idrografiche sulle acque costiere Ligustiche comprese tra l'Isola Palmaria e Capo Mele. Parte Ia — Introduzione, osservazioni meteorologiche e fisico-chimiche". Cent. Talassogr. Tirreno, Pubbl. 8, Genova, 1951.

Tully, J. P. "Oceanographic data of the western Canadian Arctic region, 1935—37". Journ. Fish. Res. Board Canada, **8**, 5, pp. 378—82, Toronto, 1952.

Utinomi, H., Yamazi, I. & Ikari, M. "The ecology of tide pools. 1. Topographical and tidal conditions as environmental factors. 2. Meteorological and hydrological conditions as environmental factors. 3. Biota of tide pools, their composition and fluctuation." Seto Mar. Biol. Lab., Contrib. 139, 140, and 141, Sirahama, 1950.

2) c Chemistry of Sea Water.

Braarud, T. & Føyn, E. "Nitrite in polluted sea-water. Observations from the Oslo Fjord 1946—1948". Avhandl. Norske Vid.-Akad. Oslo, 1. Mat.-Natur. Kl., 3, Oslo, 1951.

Cooper, L. H. N. "Chemical properties of the sea water in the neighbourhood of the Labadie Bank". Journ. Mar. Biol. Assoc. U. K., N. S., **30**, 1, pp. 21—6, Cambridge, 1951.

Dobrolonsky, S. V. "On the diurnal variations of temperature in the surface layer of the sea and on heat currents at the sea/air interface". Dok. Akad. Nauk, **45**, pp. 371—4, Leningrad, 1944. (In Russian).

Lewis, G. J. & Thompson, T. G. "The effect of freezing on the sulfate/chlorinity ratio of sea water". Journ. Mar. Res., **9**, 3, pp. 211—7, New Haven, Conn., 1950.

2) d Physical Properties.

Clark, D. D. "Streaks on natural water surfaces". Weather, **6**, 6, pp. 187—8, London, 1951.

Liebermann, L. "The effect of temperature inhomogeneities in the ocean on the propagation of sound". Journ. Acoust. Soc. America, **23**, 5, pp. 563—70, Menasha, Wis., 1951.

Rozenberg, L. D. "A new phenomenon in hydroacoustics". Dok. Akad. Nauk, **69**, pp. 175—6, Leningrad, 1949. (In Russian).

2) e Temperatures.

Bailey, W. B. & Hachey, H. B. "The vertical temperature structure of the Labrador Current". Proc. Nova Scot. Inst. Sci., **22**, Pt. 4, pp. 34—48, Halifax, 1951.

Granqvist, G. "Regular observations of temperature and salinity in the seas around Finland, July 1946—June 1950". Merentut. Julk., 150, Helsinki, 1951.

Granqvist, G. "Harmonic analysis of temperature and salinity in the sea off Finland and changes in salinity". ibid., 152, Helsinki, 1952.

Richter, J. "Über den Zusammenhang zwischen Windstärke und Wassertemperatur in der Nordsee". Ann. Meteorol., **4**, 7—9, pp. 375—9, Hamburg, 1951.

Rodewald, M. "Wassertemperaturen im Nordostatlantik und Nordmeer 1948—1951". Fischereiwelt, **4**, 3, Bremerhaven, 1952.

Tait, J. B. "On the application to marine research of the meteorological concept of accumulated temperature". Cons. Internat. Explor. Mer, Journ. du Cons., **17**, 2, pp. 111—20, Copenhague, 1951.

2) f Submarine Illumination.

Takenouti, Y. "On the transparency of sea water". Oceanogr. Mag., **2**, 4, pp. 129—35, Tokyo, 1950.

2) g Hydrodynamics.

Bowden, K. F. & Fairbairn, L. A. "Further observations of the turbulent fluctuations in a tidal current". Phil. Trans. Roy. Soc. London, Ser. A, **244**, 883, pp. 335—56, Cambridge, 1952.

Hayes, F. R., McCarter, J. A., Cameron, M. L. & Livingstone, D. A. "A further experiment on the addition of radioactive phosphorus to a lake". Nova Scot. Inst. Sci., 6th Ord. Meeting, Halifax, 1950.

McCarter, J. A., Hayes, F. R., Jodrey, L. H. & Cameron, M. L. "Exchange of materials in a lake studied by the addition of radioactive phosphorus below the thermocline". Nova Scot. Inst. Sci., 2nd Ord. Meeting, Halifax, 1949.

Munk, W. H., Groves, G. W. & Carrier, G. F. "Note on the dynamics of the Gulf Stream". Journ. Mar. Res., **9**, 3, pp. 218—38, New Haven, Conn., 1950.

2) h Currents and Oceanic Circulation.

Agenerov, V. K. "O dinamike vod Barentsova moria. (Dynamics of the Barents Sea)". Moskva, Gidromet., 130 pp., Moscow, 1946. (In Russian).

Bailey, W. B. & Hachey, H. B. "An increasing Atlantic influence in Hudson Bay". Proc. Nova Scot. Inst. Sci., **22**, Pt. 4, pp. 17—33, Halifax, 1951.

Dietrich, G. "Influences of tidal streams on oceanographic and climatic conditions in the sea as exemplified by the English Channel". Nature, **168**, 4262, pp. 8—11, London, 1951.

Dietrich, G. "Oberflächenströmungen im Kattegat, im Sund und in der Beltsee". Deutsch. Hydrogr. Zeitschr., **4**, 4—6, pp. 129—50, Hamburg, 1951.

Ford, W. L. & Fuglister, F. C. "Some new results on the behaviour of the Gulf Stream". Nova Scot. Inst. Sci., 3rd Ord. Meeting, Halifax, 1950.

Gordon, A. H. & Barlow, E. W. "Summary of weather and currents at the original ocean weather stations 'Item' and 'Jig'". Mar. Observer, **22**, 156, pp. 91—8, H. M. S. O., London, 1952.

Hansen, W. "Winderzeugte Strömungen im Ozean". Deutsch. Hydrogr. Zeitschr., **4**, 4—6, pp. 161—72, Hamburg, 1951.

Hidaka, K. & Suzuki, T. "On the secular variation of Tusima Current". Oceanogr. Mag., **1**, 1, pp. 39—42, Tokyo, 1949.

Iselin, C. O'D. "Some common characteristics of the Gulf Stream and the atmospheric jet stream". Trans. New York Acad. Sci., Ser. 2, **13**, pp. 84—6, New York, 1950.

Lauzier, L. "Effect of storms on the water conditions in the Magdalen Shallows". Journ. Fish. Res. Board Canada, **8**, 5, pp. 332—9, Toronto, 1952.

Masuzawa, J. "On the intermediate water in the Southern Sea of Japan". Oceanogr. Mag., **2**, 4, pp. 137—44, Tokyo, 1950.

Webster, J. R. & Biller, R. J. "Drift bottle releases off New Jersey; a preliminary report on experiments begun in 1948". Fish Wildlife Serv., Spec. Sci. Rep., Fish. 10, Washington, 1950.

2) i Tides and Sea Level.

Bergsten, F. "Vattenståndens varaktighet utmed svenska kusten". Geogr. Ann., Årg. 32, 3—4, pp. 165—78, Stockholm, 1950.

Fedorov, E. P. "The influence of fluctuations in the ocean level, caused by the motion of the earth's poles, on such motion". Dok. Akad. Nauk, **67**, pp. 647—50, Leningrad, 1949. (In Russian).

Hidaka, K. "Qualitative analysis of the tides". Oceanogr. Mag., **1**, 1, pp. 33—8, Tokyo, 1949.

Ichiye, T. "One type of non-disperse planetary wave". Oceanogr. Mag., **2**, 4, pp. 145—8, Tokyo, 1950.

Lacombe, H. "Les marées de la Manche". Bull. Inst. Océanogr., 989, Monaco, 1951.

Morison, J. R. "The effect of wave steepness on wave velocity". Trans. American Geophys. Union, **32**, 3, pp. 201—6, Washington, 1951.

Villain, C. "Lignes cotidales de l'océan Atlantique". Com. Cent. d'Océanogr. Etudes Côtes, Bull. d'Inform., 3. Ann., 7, pp. 237—68, Paris, 1951.

2) j Geography, Geology and Bottom Deposits.

Carruthers, J. N. & Lawford, A. L. "The deepest oceanic sounding". Nature, **169**, p. 601, London, 1952.

Denizot, G. "Les anciens rivages de la Méditerranée française". Bull. Inst. Océanogr., 992, Monaco, 1951.

Pratje, O. "Die Kieselsäureorganismen des Südatlantischen Ozeans als Leitformen in den Bodenablagerungen". Deutsch. Hydrogr. Zeitschr., **4**, 1/2, pp. 1—6, Hamburg, 1951.

Saks, V. N. "Problems of submarine valleys". Priroda, **37**, 9, pp. 32—40, Leningrad, 1948. (In Russian).

Saks, V. N. "The rate of accumulation of recent marine sediments". Priroda, **39**, 6, pp. 24—33, Leningrad, 1950. (In Russian).

Vevers, H. G. "Photography of the sea floor". Journ. Mar. Biol. Assoc. U. K., N. S., **30**, 1, pp. 101—11, Cambridge, 1951.

2) k Ice.

Prahm, G. "Die Abschmelzzeit des Eises an den deutschen Küsten zwischen Ems und Oder". Deutsch. Hydrogr. Zeitschr., **4**, 1/2, pp. 17—28, Hamburg, 1951.

le Floch, J. "Caractéristiques hydrologiques et transport des masses d'eaux dans le canal de Sicile en mars et juin 1950". Com. Cent. d'Océanogr. Etudes Côtes, Bull. d'Inform., 3. Ann., 7, pp. 281—300, Paris, 1951.

3) Plankton.

3) a Apparatus and Methods.

Barnes, H. "Horizontal plankton hauls". Cons. Internat. Explor. Mer, Journ. du Cons., **17**, 2, pp. 133—9, Copenhague, 1951.

Barnes, H. & Marshall, S. M. "On the variability of replicate plankton samples and some applications of 'contagious' series to the statistical distribution of catches over restricted periods". Journ. Mar. Biol. Assoc. U. K., N. S., **30**, 2, pp. 233—63, Cambridge, 1951.

Rae, K. M. "Continuous plankton records: Explanation and methods, 1946—49". Hull Bull. Mar. Ecol., **3**, 21, pp. 135—55, Hull, 1952.

3) b General.

Balech, E. "Contribución al conocimiento del plancton del Mar de Bellingshausen". Physics, **20**, pp. 75—91, Buenos Aires, 1947.

Davis, C. C. & Williams, R. H. "Brackish water plankton of mangrove areas in southern Florida". Ecology, **31**, 4, pp. 519—31, Brooklyn, 1950.

Fraser, J. H. "Plankton investigations from Scottish research vessels". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 91—5, Copenhague, 1950.

Tamura, T. "Observation of the plankton in drift ice". Bull. Faculty Fish., Hokkaido Univ., **1**, 3/4, pp. 134—8, Hakodate, 1951.

3) c Phytoplankton.

Braarud, T. & Hope, B. "The annual phytoplankton cycle of a landlocked fjord near Bergen (Nordåsvatn)". Rep. Norw. Fish. Mar. Invest., **9**, 16, Bergen, 1952.

Hasle, G. R. & Nordli, E. "Form variations in *Ceratium fusus* and *tripos* populations in cultures and from the sea". Avhandl. Norske Vid.-Akad. Oslo, 1. Mat.-Natur. Kl. 4, Oslo, 1951.

Knight-Jones, E. W. "Preliminary studies of nanoplankton and ultraplankton systematics and abundance by a quantitative culture method". Cons. Internat. Explor. Mer, Journ. du Cons., **17**, 2, pp. 140—55, Copenhague, 1950.

Pratje, O. "Die Kieselsäureorganismen des Südatlantischen Ozeans als Leitformen in den Bodenablagerungen". Deutsch. Hydrogr. Zeitschr., **4**, 1/2, pp. 1—6, Hamburg, 1951.

Steemann Nielsen, E. "The marine vegetation of the Isefjord. A study on ecology and production". Medd. Komm. Danmarks Fisk.- og Havunders., Ser. Plankton, **5**, 4, København, 1951.

3) d Zooplankton.

Braarud, T. "Morphological observations on marine dinoflagellate cultures (*Porella perforata, Goniaulax Tamarensis, Protoceratium reticulatum*)". Avhandl. Norske Vid.-Akad. Oslo, 1. Mat.-Natur. Klasse, 11, Oslo, 1945.

Brodskiy, K. A. "On the zoogeography of the deeps of the north-west part of the Pacific Ocean". Dok. Akad. Nauk S. S. S. R., N. S., **60**, 6, Moscow and Leningrad, 1948. (In Russian).

Fleury, J. "Principales 'espèces planctoniques' recueillies par la 'Ville d'Ys' (1927) et le 'Victoria' (1946—47) sur les Bancs de Terre-Neuve". Cons. Internat. Explor. Mer, Ann. Biol., **6**, p. 47, Copenhague, 1950.

Fraser, J. H. "List of rare exotic species found in the plankton by the Scottish research vessels in 1949". Cons. Perm. Internat. Explor. Mer, Ann. Biol., **6**, pp. 95—9, Copenhague, 1950.

Pearson, J. C. "The young of some marine fishes taken in lower Chesapeake Bay, Virginia, with special reference to the gray sea trout *Cynoscion regalis* Bloch". U. S. Dept. Int., Fish & Wildlife Serv., Fish. Bull. 36, Washington 1941.

Rees, C. B. "Continuous plankton records: The decapod larvae in the North Sea, 1947—49". Hull Bull. Mar. Ecol., **3**, 22, pp. 157—84, Hull, 1952.

3) e Physiology and Behaviour.

Braarud, T. & Pappas, I. "Experimental studies on the dinoflagellate *Peridinium triquetrum* (Ehrb.) Lebour". Avhandl. Norske Vid.-Akad. Oslo, 1. Mat.-Natur. Kl., 2, Oslo, 1951.

Braarud, T. & Rossavik, E. "Observations on the marine dinoflagellate *Prorocentrum micans* (Ehrb.) in culture". Avhandl. Norske Vid.-Akad. Oslo, 1. Mat.-Natur. Kl., 1, Oslo, 1951.

Harding, J. P., Marshall, S. M. & Orr, A. P. "Time of egg-laying in the planktonic copepod *Calanus*". Nature, **167**, 4258, p. 933, London, 1951.

Takeda, N. "Experimental studies on the effect of external agencies on the sexuality of a marine copepod". Phys. Zool., **23**, 4, pp. 288—301, Chicago, 1950.

Tokioka, T. "Notes on the development of the eye and the vertical distribution of Chaetognatha". Natura et Cultura, 1, Kyoto, 1950.

4) Organic Production.

4) a General.

Wilson, D. P. "A biological difference between natural sea waters". Journ. Mar. Biol. Assoc. U. K., N. S., **30**, 1, pp. 1—20, Cambridge, 1951.

4) b Bacteria.

Fujita, H. "A note on Pfarls coefficient for the increase of bacteria in a culture medium". Bull. Japan. Soc. Sci. Fish., **17**, 1, pp. 24—6, Tokyo, 1951.

5) Bottom Fauna and Flora.

5) a Apparatus and Methods.

Galtsoff, P. S. & Loosanoff, V. L. "Natural history and method of controlling the starfish (*Asterias forbesi*, Desor)". U. S. Dept. Int., Fish. Bull. 31, Washington, 1939.

Greze, V. N. "Bottom plankton, its role in the nutrition of fish, and methods of valuation". Zool. Zhurn., **30**, 1, pp. 44—50, Moscow, 1951. (In Russian).

Vevers, H. G. "Photography of the sea floor". Journ. Mar. Biol. Assoc. U. K., N. S., **30**, 1, pp. 101—11, Cambridge, 1951.

5) b Systematics and Development.

Bacci, G. & Oddo, F. "Ricerche serologiche sulla sistematica del genere *Venerupis* Lam. (Mollusca bivalva)". Pubbl. Staz. Zool. Napoli, **21**, 2, pp. 117—23, Napoli, 1947.

Cherbonnier, G. "Primera Expedición Antarctica Chilena. Une nouvelle Holothurie incubatrice de l'Antarctique chilien; *Cucumaria Vaneya* n. sp." Revista Biol. Mar., **1**, 3, pp. 229—32, Valparaiso, 1949.

Cherbonnier, G. "Une nouvelle Holothurie dendrochirote des côtes du Cameroun: *Cladodactyla Monodi* n. sp.". Bull. Mus. Nation. d'Hist. Nat., 2e Sér., **22**, 3, pp. 375—7, Paris, 1950.

Cherbonnier, G. "Sur la présence au Gabon de *Hemioedema goreensis* Cherb.". ibid., 2e Sér., **22**, 3, p. 378, Paris, 1950.

Cushman, J. A. "Foraminifera, their classification and economic use". 4th Edit., Harvard Univ. Press, Cambridge, Mass., 1950.

Dales, R. P. "Notes on the reproduction and early development of the cirratulid *Tharyx marioni* (St. Joseph)". Journ. Mar. Biol. Assoc. U. K., N. S., **30**, 1, pp. 113—7, Cambridge, 1951.

Dales, R. P. "Observations on the structure and life history of *Autolytus prolifer* (O. F. Müller)". ibid., **30**, 1, pp. 119—28, Cambridge, 1951.

Fisher, W. K. "New genera and species of echiuroid and sipunculoid worms". Proc. U. S. Natur. Mus., **97**, 3218, pp. 351—72, Washington, 1947.

Galtsoff, P. S. & Loosanoff, V. L. "Natural history and method of controlling the starfish (*Asterias forbesi*, Desor)". U. S. Dept. Int., Fish. Bull. 31, Washington, 1939.

Hedgpeth, J. W. "The Picnogonida of the western North Atlantic and the Caribbean". Proc. U. S. Nat. Mus., **97**, pp. 157—342, Washington, 1948.

Kott, P. "*Corella halli* n. sp., a new ascidian from the English Channel". Journ. Mar. Biol. Assoc. U. K., N. S., **30**, 1, pp. 33—6, Cambridge, 1951.
Leone, C. A. "A serological analysis of the systematic relationship of the brachyuran crab *Geryon quinquedens*". Biol. Bull., **100**, 1, pp. 44—8, Lancaster, Pa., 1951.
Littleford, R. A. & Truitt, R. B. "Variation of *Dactylometra quinquecirrha*". Science, **86**, 2236, pp. 426—7, Lancaster, Pa., 1937.
Medawar, P. B. "Asymmetry of larval *Amphioxus*". Nature, **167**, 4256, pp. 852—3, London, 1951.
Millar, R. H. "The development and early stages of the ascidian *Pyura squamulosa* (Alder)". Journ. Mar. Biol. Assoc. U. K., N. S., **30**, 1, pp. 27—31, Cambridge, 1951.
Serène, R. "Cas de malformations chez les Stomatopodes". Bull. Mus. Nation. d'Hist. Nat., 2e Sér., **22**, 3, pp. 341—3, Paris, 1950.
Tokioka, T. "Ascidians from the Palao Islands. 1". Publ. Seto Mar. Biol. Lab., **1**, 3, pp. 115—50, Sirahama, 1950.
Werner, B. & Grell, K. G. "Die amerikanische Pantoffelschnecke *Crepidula fornicata* L." Jena, 1950.
Williamson, D. I. "On the distinctive characters of *Orchestia mediterranea* Da Costa and *Orchestia gammarella* (Pallas)". Rep. Dove Mar. Lab. Cullercoats, 3. Ser., 12, pp. 63—5, Newcastle-upon-Tyne, 1951.

5) c Distribution and Ecology.

Backlund, H. O. "Wrack fauna of Sweden and Finland. Ecology and chorology". Opuscula Entomolog. Suppl. 1945, Lund, 1945.
Barnes, H. & Bagenal, T. B. "Observations on *Nephrops norvegicus* (L.) and on an epizoic population of *Balanus crenatus* Brug.". Journ. Mar. Biol. Assoc. U. K., **30**, 2, pp. 369—80, Cambridge, 1951.
Blegvad, H. "Fluctuations in the amounts of food animals of the bottom of the Limfjord in 1928—1950". Rep. Dan. Biol. Stat., 53, pp. 3—16, Copenhagen, 1951.
Dahl, E. "Epicaridea and Rhizocephala from northern Norway, with a discussion of the bathymetrical distribution of Rhizocephala". Tromsø Mus. Årsh. Naturhist. Avd., 37, **69** (1946), 1, Tromsø, 1949.
Evans, F. G. C. "An analysis of the behaviour of *Lepidochitona cinereus* in response to certain physical features of the environment". Journ. Anim. Ecol., **20**, 1, pp. 1—10, Cambridge, 1951.
Goodbody, I. M. "Notes on Tunicata from Dublin Bay". Irish Natur. Journ., 10, pp. 77—80, Belfast, 1950.
Jones, N. S. "The bottom fauna off the south of the Isle of Man". Journ. Anim. Ecol., **20**, 1, pp. 132—44, Cambridge, 1951.
de Laubenfels, M. W. "Ecology of the sponges of a brackish water environment at Beaufort, N. C." Ecol. Monogr., **17**, 1, pp. 31—46, Durham, N. C., 1947.
Mars, P. "Euryhalinité de quelques Mollusques méditerranéens". Vie et Milieu, **1**, 4, pp. 441—8, Paris, 1950.
Mistakidis, M. N. "Quantitative studies of the bottom fauna of the Essex oyster grounds". Min. Agric. Fish., Fish. Invest., Ser. 2, **17**, 6, H. M. S. O., London, 1951.
Piemeisel, R. L. "Causes affecting change and rate of change in a vegetation of annuals in Idaho". Ecology, **32**, 1, Lancaster, Pa., 1951.
Poulsen, E. M. "Changes in the frequency of larger bottom invertebrates in the Limfjord in 1927—1950". Rep. Dan. Biol. Stat., 53, pp. 17—35, Copenhagen, 1951.
Rees, W. J. "Giant squid stranded in Cornwall". Bull. Brit. Mus. Natur. Hist., **1**, 2, p. 29, London, 1950.
Spooner, G. M. "On *Gammarus zaddachi oceanicus* Segerstråle". Journ. Mar. Biol. Assoc. U. K., N. S., **30**, 1, pp. 129—47, Cambridge, 1951.
Stephenson, T. A. & A. "Life between tide-marks in North America. 1. The Florida Keys". Journ. Ecol., **38**, 2, pp. 354—402, London, 1950.
Stoppford, S. C. "An ecological survey of the Cheshire foreshore of the Dee estuary". Journ. Anim. Ecol., **20**, 1, pp. 103—22, Cambridge, 1951.
Utinomi, H., Yamazi, I. & Ikari, M. "The ecology of tide pools. 1. Topographical and tidal conditions as environmental factors. 2. Meteorological and hydrological conditions as environmental factors. 3. Biota of tide pools, their composition and fluctuation." Seto Mar. Biol. Lab., Contrib. 139, 140, and 141, Sirahama, 1950.

5) d Physiology and Behaviour.

Barnes, H., Crisp, D. J. & Powell, H. T. "Observations on the orientation of some species of barnacles". Journ. Anim. Ecology, **20**, 2, pp. 227—41, Cambridge, 1951.
Barnes, H. & Powell, H. T. "The growth-rate of juvenile *Asterias rubens* L.". Journ. Mar. Biol. Assoc. U. K., **30**, 2, pp. 381—5, Cambridge, 1951.

Chipperfield, P. N. J. "The breeding of *Crepidula fornicata* (L.) in the River Blackwater, Essex". Journ. Mar. Biol. Assoc. U. K., N. S., **30**, 1, pp. 49—71, Cambridge, 1951.

Enami, M. "The sources and activities of two chromatophorotropic hormones in crabs of the genus *Sesarma*. 1. Experimental analyses". Biol. Bull., **100**, 1, pp. 28—43, Lancaster, Pa., 1951.

Hashimoto, Y., Matsumoto, S. & Hibiya, T. "Comparative studies on the stomachal plates in an Opisthobranch, *Dolabella scapula*". Bull. Japan. Soc. Sci. Fish., **17**, 2, pp. 1—6, Tokyo, 1951.

Pérès, J. M. "Recherches sur le sang et les organes neuraux des Tuniciers". Ann. Inst. Océanogr., **21**, 5, pp. 229—359, Monaco, 1943.

Tixier-Durivault, A. "Contribution à l'étude du métabolisme du calcium et du fer chez l'*Alcyonium palmatum* Pallas". Ann. Inst. Océanogr., **20**, pp. 371—9, Monaco, 1940.

Umezawa, S. & Asida, T. "On the hardening of the fertilization membrane of sea urchin eggs". Journ. Faculty Sci. Hokkaido Univ., Zool., **10**, 1, pp. 38—44, Sapporo, 1950.

Werner, B. "Über die Bedeutung der Wasserstromerzeugung und Wasserstromfiltration für die Nahrungsaufnahme der ortsgebundenen Meeresschnecke *Crepidula fornicata* L. (Gastropoda Prosobranchia)". Zool. Anzeiger, **146**, 5/6, pp. 97—113, Leipzig, 1951.

Williamson, D. I. "On the mating and breeding of some semi-terrestrial amphipods". Rep. Dove Mar. Lab. Cullercoats, 3. Ser., 12, pp. 49—61, Newcastle-upon-Tyne, 1951.

Yamazi, I. "Autotomy and regeneration in Japanese sea-stars and ophiurans. 1. Observation on a sea-star, *Coscinasterias acutispina* Stimpson and four species of ophiurans". Annot. Zool. Japon., **23**, 4, pp. 175—86, Tokyo, 1950.

5) e Parasitic Forms.

Faure-Fremiet, E. "The marine sand-dwelling ciliates of Cape Cod". Biol. Bull., **100**, 1, pp. 59—70, Lancaster, Pa., 1951.

Fretter, V. "*Turbonilla elegantissima* (Montagu), a parasitic opisthobranch". Journ. Mar. Biol. Assoc. U. K., N. S., **30**, 1, pp. 37—47, Cambridge, 1951.

Jensen, A. S. "Do the Naticidae drill by mechanical or by chemical means?". Nature, **167**, 4257, pp. 901—2, London, 1951.

5) f Marine Plants.

Aleem, A. A. "Phycomycètes marins parasites de Diatomées et d'Algues dans la région de Banyuls-sur-Mer (Pyrenées-Orientales)". Vie et Milieu, **1**, 4, pp. 421—40, Paris, 1950.

Burrows, E. M. & Lodge, S. "Autecology and the species problem in *Fucus*". Journ. Mar. Biol. Assoc. U. K., N. S., **30**, 1, pp. 161—76, Cambridge, 1951.

Causei, N. C. & others. "Influence of environment factors upon the growth of *Gracilaria confervoides*". Duke Univ. Mar. Stat., Bull. 3, pp. 19—24, Durham, N. C., 1946.

Frenkel, A. W. & Rieger, S. "Photoreduction in algae". Nature, **167**, 4260, p. 1030, London, 1951.

Hustedt, F. & Aleem, A. A. "Littoral diatoms from the Salstone, near Plymouth". Journ. Mar. Biol. Assoc. U. K., N. S., **30**, 1, pp. 177—96, Cambridge, 1951.

Mikkelsen, V. M. "Præstø Fjord. The development of the postglacial vegetation and a contribution to the history of the Baltic Sea". Dansk botanisk Arkiv, **13**, 5, Kjøbenhavn, 1949.

Obata, Y., Igarashi, H. & Matano, K. "Studies on the flavor of seaweeds 1. On the component of the flavor of some green algae". Bull. Japan. Soc. Sci. Fish., **17**, 2, pp. 20—2, Tokyo, 1951.

Steemann Nielsen, E. "The marine vegetation of the Isefjord. A study on ecology and production". Medd. Komm. Danmarks Fisk.- og Havunders., Ser. Plankton, **5**, 4, København, 1951.

Vatova, A. "Fenologia delle Alghe marine di Rovigno". Nova Thalass. Inst. Biol. Mar., **1**, 1, pp. 43—69, Venezia, 1948.

Walker, F. T. "Sublittoral seaweed survey of the Orkney Islands". Journ. Ecol., **38**, 1, pp. 139—65, Cambridge, 1950.

6) Fish.

6) a Systematics, Morphology and Development.

Chernyj, S. I. "Recherches chez les téléostéens, sur les adaptations fonctionelles de la ceinture scapulaire aux mouvements en rapport avec le mode d'alimentation". Zool. Zhurn. U. R. S. S., **28**, 5, pp. 1439—46, Moscow, 1949. (In Russian).

Clothier, C. R. "A key to some Southern California fishes based on vertebral characters". Bull. Div. Fish. Game, Calif. Fish., 79, Sacramento, 1950.

Felin, F. E. "Growth characteristics of the poeciliid fish *Platypoecilus maculatus*". Copeia, 1, pp. 15—28, Ann Arbor, Mich., 1951.

Zambriborshch, F. S. "On some anatomical characters of the Black Sea mullet". Zool. Zhurn., **30**, 2, pp. 143—8, Moscow, 1951. (In Russian).

6) b Distribution and Fluctuations.

Arnold, E. L. "Northward dispersal of warm-water marine fishes in southern New England during the summer of 1949". Copeia, 1, pp. 87—8, Ann Arbor, Mich., 1951.

Tambovtsev, B. M. "The common garfish in the White Sea". Priroda, 10, pp. 70—1, Leningrad, 1948. (In Russian).

6) c Physiology and Behaviour.

Baldwin, E. "Some comparative aspects of the biochemistry of fish". Biochem. Fish, Biochem. Soc. Symposia, 6, pp. 3—7, Cambridge, 1951.

Ellis, M. M. "Temperature and fishes". U. S. Dept. Int., Fish Wildlife Serv., Fish. Leaflet 221, Washington, 1947.

Engelhardt, A. "Die Temperaturabhängigkeit der Erregungsleitungsgeschwindigkeit in Kalt- und Warmblüternerven". Zeitschr. vergl. Physiol., **33**, 2, pp. 125—8, Berlin, 1951.

Goodwin, T. W. "Carotenoids in fish". Biochem. Fish, Biochem. Soc. Symposia, 6, pp. 63—82, Cambridge, 1951.

Grandilevskaia-Dieksbach, M. L. & Troitskaia, V. I. "Feeding and growth of the Ladoga whitefish (*Coregonus albula* infraspecies *ladogae* Pravdin)". Zool. Zhurn., **30**, 3, pp. 253—66, Moscow, 1951. (In Russian).

Gudimovich, P. K. "Short summary on fecundity of the Black Sea sultanka and its spawning". Zool. Zhurn., **30**, 1, pp. 85—6, Moscow, 1951. (In Russian).

Hamoir, G. "The proteins of fish". Biochem. Fish, Biochem. Soc. Symposia, 6, pp. 8—27, Cambridge, 1951.

Haslewood, G. A. D. "Bile salts of fish". Biochem. Fish, Biochem. Soc. Symposia, 6, pp. 83—5, Cambridge, 1951.

Kow, T. A. "The food and feeding relationships of the fishes of Singapore Straits". Colonial Office, Fish. Publ., **1**, 1, H. M. S. O., London, 1950.

Lovern, J. A. "The chemistry and metabolism of fats in fish". Biochem. Fish, Biochem. Soc. Symposia, 6, pp. 49—62, Cambridge, 1951.

Morosov, A. V. & Dubrovskaia, K. P. "On the coefficient of nourishment of fish". Zool. Zhurn., **30**, 3, pp. 267—73, Moscow, 1951. (In Russian).

Olivereau, M. & Leloup, J. "Variations du rapport hépatosomatique chez la Roussette (*Scyllium canicula* L.) au cours du développement et de la reproduction". Vie et Milieu, **1**, 4, pp. 377—420, Paris, 1950.

Peters, H. M. "Beiträge zur ökologischen Physiologie des Seepferdes (*Hippocampus brevirostris*)". Zeitschr. vergl. Physiol., **33**, 3, pp. 207—65, Berlin, 1951.

Pora, E. A. "Les réactions aux variations de salinité. 24. Influence du facteur salinité sur la vie aquatique, spécialement dans la Mer Noire". Ann. Acad. Republ. popul. Rome, **2**, 10, pp. 277, 325, Rome, 1949.

Shewan, J. M. "The chemistry and metabolism of the nitrogenous extractives in fish". Biochem. Fish, Biochem. Soc. Symposia, 6, pp. 28—48, Cambridge, 1951.

Shmalhausen, I. I. "Functional significance of primitive form of attachment of the maxillary arch to the cranium of fishes". Zool. Zhurn., **30**, 2, pp. 149—64, Moscow, 1951. (In Russian).

Simidu, W. & Takuma, H. "Studies on the muscle of the aquatic animals. 9. The change of the heat coagulation curve of the fish muscle plasma". Bull. Japan. Soc. Sci-Fish., **17**, 4, pp. 5—7, Tokyo, 1951.

Strel'tsova, S. V. "Cutaneous respiration of fish". Dok. Akad. Nauk S. S. S. R., **76**, 1, p. 157, Leningrad, 1951. (In Russian).

Thomson, J. M. "Growth and habits of the sea mullet, *Mugil dobula* Günther, in western Australia". Austral. Journ. Mar. Freshw. Res., **2**, 2, pp. 193—225, Melbourne, 1951.

Vinogradov, K. A. & Tkacheva, K. "Sur la fécondité des poissons littoraux de la Mer Noire". Dok. Akad. Nauk S. S. S. R., **65**, 3, pp. 381—4, Leningrad, 1949. (In Russian).
Woldring, S. & Dirken, M. N. J. "Unit activity in the medulla oblongata of fishes". Journ. Exper. Biol., **28**, 2, pp. 218—20, Cambridge, 1951.

6) d Parasites and Diseases.

Bonham, K. & Guberlet, J. E. "Notes on *Microcotyle sebastis* Goto from Puget Sound". Journ. Parasitol., **23**, 3, pp. 281—90, Urbana, Ill., 1937.
Bonham, K. "Some monogenetic trematodes of Puget Sound fishes". Univ. Washington Press, Stud. Honoring Trevor Kincaid, Washington, 1950.
Bonham, K. & Guberlet, J. E. "Ectoparasitic trematodes of Puget Sound fishes. Acanthocotyle". American Midland Naturalist, **20**, 3, pp. 590—602, Notre Dame, Ind., 1938.
Hodgkiss, W. & Shewan, J. M. "*Pseudomonas* infection in a plaice". Journ. Pathol. Bacteriol., **62**, 4, pp. 655—7, London, 1950.
Hollis, E. H. & Coker, C. M. "A trematode parasite of the genus *Clinostomum* new to the shad, *Alosa sapidissima*". Journ. Parasit., **34**, 6, pp. 493—5, Urbana, Ill., 1948.
Perlmutter, A. "The positional pattern of the copepod parasite *Sphyrion lumpi* on the rosefish, *Sebastes marinus*, and its relationship to the behaviour of the fish". Copeia, 1, pp. 97—8, Ann Arbor, Mich., 1951.

7) Marine Fisheries.

7) a Commercial Fisheries: Statistical.

van Buren, H. T. "The sponge fishing industry in Libya (Africa)". U. S. Dept. Int., Fish Wildlife Serv., Fish. Leaflet 341, Washington, 1949.

7) b Fish Technology.

Amand, K. "Chemical studies on the freshness test of aquatic food products". Bull. Tokai Regional Fish. Res. Lab., 1, pp. 128—31, Tokyo, 1950.
Banks, A. "Freezing and cold storage of herrings". Fishing News, 1983, pp. 13 & 15, London, 1951.
Banks, A. & Eddie, G. C. "The quick-freezing of kippers". D. S. I. R. Food Invest. Mem., 670, Aberdeen, 1950.
Bucher, D., Heerdt, M. & Osterhaug, K. "Bibliography of the preservation of fishery products by freezing. Part 1. Period to January 1945". U. S. Dept. Int. Fish. Wildlife Serv., Fish. Leaflet 265, Washington, 1945.
Dassow, J. "Bibliography of the preservation of fishery products by freezing. Part 2. Period of January 1945 to December 1947, inclusive". U. S. Dept. Int., Fish Wildlife Serv., Fish. Leaflet 265, Suppl., Washington, 1949.
Hanson, S. W. F. & Lovern, J. A. "The liquid ensilage of fish for animal feeding stuffs". Fishing News, 1988, p. 11, London, 1951.
Harrison, J. S. M. & Schmidt, P. J. "Mechanical brining for salt herring". Prog. Rep. Pacific Coast Stat., 86, pp. 3—5, Vancouver, B. C., 1951.
Jarvis, N. D. "Curing of fishery products". U. S. Dept. Int., Fish Wildlife Serv., Res. Rep. 18, Washington, 1950.
Lee, C. F. "Technological studies of the starfish. Part 1. Starfish control — its economic necessity and methods used". U. S. Dept. Int., Fish Wildlife Serv., Fish. Leaflet 391, Washington, 1951.
Lovern, J. A. "Drying in the fish meal industry". Fishing News, 1987, pp. 8—9, London, 1951.
Lovern, J. A. & Godden, W. "The possible use of fish guts as food for animals". D. S. I. R. Food Invest. Mem., 680, Aberdeen, 1950.
Reay, G. A. "The preservation and utilization of marine fish in the United Kingdom". D. S. I.R. Food Invest. Mem., 675, Aberdeen, 1950.
Reay, G. A. "The utilisation of herring". Fishing News, 1980, pp. 8—9, London, 1951.
Shewan, J. M. "Salage, fumage et déshydratation du poisson". D. S. I. R. Food Invest. Mem., 668, Aberdeen, 1950.
Stansby, M. E. "Composition of fish". U. S. Dept. Int., Fish Wildlife Serv., Fish. Leaflet 116, Washington, 1947.
Wood, A. L. "The drying of salt fish". Fishing News, 1982, pp. 12—5, London, 1951.

7) c Fishing Vessels and Gear.

Firth, F. E. "Fighting fibres and comparable values of fibres for use in commercial fisheries". U. S. Dept. Int., Fish Wildlife Serv., Fish. Leaflet 111, Chicago, 1945.
Kristensen, M. O. "Forsøksfiske med nye redskaper i Lofoten". Årsber. vedk. Norges Fisk., 1949, 7, pp. 7—46, Bergen, 1950.
Kristensen, M. O. "Forsøksdrift med motortrålere av størrelse 75—100 fot". ibid., 1949, 7, pp. 58—87, Bergen, 1950.
Kristensen, M. O. "Forsøksfiske med 'Pareja' slepenot". ibid., 1949, 7, pp. 88—96, Bergen, 1950.
Kristensen, M. O. & Rokstad, G. "Forsøk med nylon i fiske og fangstredskaper". Årsber. vedk. Norges Fisk., 1949, 7, pp. 97—102, Bergen, 1950.
Parrish, B. B. "Fishing capacities of Lowestoft and Aberdeen trawls when used on flatfish grounds". Cons. Internat. Explor. Mer, Journ. du Cons. **17**, 2, pp. 156—71, Copenhague, 1951.
Phillips, J. B. "Lampara net-pulling gurdies". California Fish Game, **37**, 2, pp. 121—3, San Francisco, 1951.
Whiteleather, R. T. "Balloon trawl construction (Long Island type)". U. S. Dept. Int., Fish Wildlife Serv., Fish. Leaflet 245, Washington, 1948.

8) Marine Fishery Investigations.

8) a Stocks and Effects of Fishing.

Boerema, L. K. "The Dutch fishery for demersal seafish in 1949". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 126—30, Copenhague, 1950.
Kolloen, L. N. "Tagging and marking fish". U. S. Dept. Int., Fish Wildlife Serv., Fish. Leaflet 113, Chicago, 1945.
Margetts, A. R. "A report on recent changes in the English North Sea demersal fisheries". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 130—1, Copenhague, 1950.
Meyer, P. F. "Die Dampferfischerei in der Ostsee während der Kriegsjahre 1939/45 und ihre Bedeutung für die Fischwirtschaft und Fischereiwissenschaft (Biol. Teil 1)". Ber. Deutsch. wiss. Komm. f. Meeresf. N. F., **12**, 2, pp. 168—209, Stuttgart, 1951.
Tiller, R. E. "A five-year study of the striped bass fishery of Maryland, based on analyses of the scales". Chesapeake Biol. Lab., Publ. 85, Solomon Isl., Maryland, 1950.
Willer, A. "Über Nutzfischzonen im europäischen Nordmeer". Ber. Deutsch. wiss. Komm. f. Meeresf. N. F., **12**, 2, pp. 139—67, Stuttgart, 1951.

8) b Cod.

Eggvin, J. "Ekkoskreimelding under Lofotfisket". Årsber. vedk. Norges Fisk., 1949, 7, pp. 47—50, Bergen, 1950.
Kristensen, M. O. "Forsøk med lakefrossen og tørrfrossen agnsild under skreifisket i Lofoten". Årsber. vedk. Norges Fisk., 1949, 7, pp. 51—7, Bergen, 1950.
Rasmussen, B. "Observations on cod during the cruise of M/S 'Vardholm' in 1949". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 40—2, Copenhague, 1950.

8) d Hake.

Margetts, A. R. "Trawling for hake on newly discovered fishing grounds". Cons. Internat. Explor. Mer, Ann. Biol., **6**, p. 50, Copenhague, 1950.

8) e Other Gadoids.

Desbrosses, P. "Southern North Sea. Merlan (*Gadus merlangus* L.)". Cons. Internat. Explor. Mer, Ann. Biol., **6**, p. 132, Copenhague, 1950.

8) f Plaice.

Jensen, A. J. C. "Transition Area. Plaice." Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 148—9, and 150, Copenhague, 1950.
Jensen, A. J. C. & Molander, A. R. "Plaice (0 and I-groups)". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 146—8, Copenhague, 1950.
Poulsen, E. M. "Plaice (the Limfjord stock)". Cons. Internat. Explor. Mer., Ann. Biol., **6**, pp. 149—50, Copenhague, 1950.
Poulsen, E. M. "Plaice (transplantation)". ibid., **6**, pp. 150—1, Copenhague, 1950.
Rae, B. B. "Northern North Sea. Plaice. Preliminary survey". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 109—10, Copenhague, 1950.

8) g Sole.

Desbrosses, P. "La sole des côtes de Bretagne". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 52—3, Copenhague, 1950.

8) h Halibut.

McIntyre, A. D. "Halibut. Statistics for north-west grounds 1936—47". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 37—8, Copenhague, 1950.

McIntyre, A. D. "Halibut. North Sea statistics, 1930—47". ibid., **6**, p. 110, Copenhague, 1950.

8) i Other Pleuronectidae.

Jensen, A. J. C. "Turbot and flounder. Young fish. Danish coasts". Cons. Internat. Explor. Mer, Ann. Biol., **6**, p. 151, Copenhague, 1950.

Kirkegaard, J. B. & Knudsen, J. "Dab (Danish waters)". Cons. Internat. Explor. Mer, Ann. Biol., **6**, p. 152, Copenhague, 1950.

Manzer, J. I. "Growth in lemon sole in northern Hecate Strait". Prog. Rep. Pacific Coast Stat., 86, pp. 13—5, Vancouver, B. C., 1951.

Molander, A. R. "Turbot and flounder. Young Fish. Swedish Coasts". Cons. Internat. Explor. Mer, Ann. Biol., **6**, p. 151, Copenhague, 1950.

Poulsen, E. M. "Flounder and turbot. Limfjord stock". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 151—2, Copenhague, 1950.

Poulsen, E. M. "Dab. Limfjord stock". Cons. Internat. Explor. Mer, Ann. Biol., **6**, p. 152, Copenhague, 1950.

8) j Herring.

Alander, H. "Baltic herring". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 191—2, Copenhague, 1950.

Devold, F. "Fiskeridirektoratets sildetokt med M/S 'Vartdal' 1949". Årsber. vedk. Norges Fisk., 1949, 7, pp. 128—36, Bergen, 1950.

Devold, F. "Norwegian herring investigations 1949". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 167—9, Copenhague, 1950.

Eggvin, J. "Les conditions océanographiques realisées le long des côtes de Norvège au cours des dernières années et leur répercussion sur la pêche". Natur. Norge, **72**, 9, pp. 267—76, Bergen, 1948. (In Norwegian).

Fridriksson, Á. "On the herring of the north coast of Iceland during the summer of 1949". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 162—7, Copenhague, 1950.

Fridriksson, Á. & Timmermann, G. "Herring spawning grounds off the south coast of Iceland during spring 1950". Cons. Internat. Explor. Mer, Journ. du Cons., **17**, 2, pp. 172—80, Copenhague, 1951.

Gilis, C. "Concentrations of full herring exploited by the Belgian herring trawlers in 1949". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 183—9, Copenhague, 1950.

Hodgson, W. C. "The East Anglian herring fishery in 1949". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 175—7, Copenhague, 1950.

Hodgson, W. C. "Spotting shoals with the recording echo sounder". Cons. Internat. Explor. Mer, Rapp. et Proc.-Verb., **128**, 1, pp. 47—8, Copenhague, 1951.

Jensen, A. J. C. "Herring on the Fladen Ground, at Esbjerg, and in the Skagerak and northern Kattegat". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 173—5, Copenhague, 1950.

Jensen, A. J. C. "Herring in the southern Kattegat, the Belt Sea, and at Bornholm". ibid., **6**, pp. 190—1, Copenhague, 1950.

Krefft, G. & Schüler, F. "Beobachtungen über die Tiefenverteilung von Heringsschwärmen in der nördlichen und mittleren Nordsee im August 1950". Fischereiwelt, **3**, 6, pp. 93—5, Bremerhaven u. Hamburg-Altona, 1951.

Saville, A. "Herring. Young stages (Scottish investigations)". Cons. Internat. Explor. Mer, Ann. Biol., **6**, p. 169, Copenhague, 1950.

Tåning, Å. V. "Marking of herring in the North Sea". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 170—1, Copenhague, 1950.

de Veen, J. & Boerema, L. K. "The Dutch herring fisheries in 1949". Cons. Internat. Explor. Mer, Ann. Biol., **6**, p. 177, Copenhague, 1950.

Wood, H. "Herring. Commercial fish. Scotland 1949". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 171—3, Copenhague, 1950.

8) k Sardine and other Clupeoids.

Blackburn, M. "'Condition rings' on scales of the European pilchard, *Sardina pilchardus* (Walbaum)". Cons. Internat. Explor. Mer, Journ. du Cons., **17**, 2, pp. 181—95, Copenhague, 1951.

Blackburn, M. "Races and populations of the Australian pilchard, *Sardinops neopilchardus* (Steindachner)". Austral. Journ. Mar. Freshw. Res., **2**, 2, pp. 179—92, Melbourne, 1951.

Dannevig, G. "Sprat (Norwegian investigations)". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 110—1, Copenhague, 1950.

Heldt, H. "*Sardinella granigera* (*S. granigera* C. V.). Espèce nouvelle pour la faune ichthyologique tunisienne". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 69—70, Copenhague, 1950.

Krvaric, M. & Muzinic, R. "Investigation into the fat content in the sardine tissues. (*Clupea pilchardus* (Walb.))". Acta Adriatica, **4**, 8, Split, 1950.

Marr, J. C. "Apparent abundance of the pilchard (*Sardinops caerulea*) off Oregon and Washington, 1935—43, as measured by the catch per boat". U. S. Dept. Int. Fish Wildlife Serv., Fish. Bull. 52, Washington, 1950.

Massuti, M., Valls, T. & Navarro, F. "La sardinelle ou allache des Baléares. (Juillet 1948—Mai 1949)". Cons. Internat. Explor. Mer, Ann. Biol., **6**, p. 66—7, Copenhague, 1950.

Muzinic, R. "Tagging of sardine (*Clupea pilchardus* (Walb.)) in the Adriatic in 1949". Acta Adriatica, **4**, 7, Split, 1950.

Navaz, J. M. & Navarro, F. "Anchois (*Engraulis encrasicholus* L.) à la côte Basque (1948—49)". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 68—9, Copenhague, 1950.

Walford, L. A. & Mosher, K. H. "Studies on the Pacific pilchard or sardine (*Sardinops caerulea*). 2. Determination of age of juveniles by scales and otoliths. 3. Determination of age of adults by scales, and effect of environment on first year's growth as it bears on age determination." U. S. Dept. Int., Fish Wildlife Serv., Spec. Sci. Rep. Fish., 15, pp. 31—95, 96—131, Washington, 1950.

Yokota, T. "Studies on the sardine stock in the Hyuganada II. Estimation of the amount of sardine stock (from 1935 to 1941)". Bull. Japan. Soc. Sci. Fish., **17**, 1, pp. 5—8, Tokyo, 1951.

8) l Tunny and Mackerel.

le Gall, J. "Maquereau (*Scomber scombrus* L.). Observations faites en 1949 sur sa biologie". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 70—1, Copenhague, 1950.

le Gall, J. "Thon Rouge (*Thunnus thynnus* L.) dans les parages de Saint Jean de Luz, en 1949". ibid., **6**, p.71, Copenhague, 1950.

le Gall, J. "Germon (*Germo alalunga* Gmelin). Observations complémentaires sur sa biologie". ibid., **6**, pp. 73—6, Copenhague, 1950.

Lozano, F. "Germon (*Germo alalunga* Gmelin) de Galice". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 77—8, Copenhague, 1950.

Lüling, K. H. "Die Thunfischanlandungen in der Schleppnetz-Heringssaison 1949 und 1950". Fischereiwelt, **3**, 6, pp. 90—2, Bremerhaven u. Hamburg-Altona, 1951.

Navaz, J. M. "Thon Rouge (*Thunnus thynnus* L.) de la côte Basque". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 71—2, Copenhague, 1950.

Navaz, J. M. "Germon (*Germo alalunga* Gmelin) à la côte Basque". ibid., **6**, p. 76, Copenhague, 1950.

8) m Other Commercial Species.

Bonham, K. "Preliminary report on the soupfin shark fishery in Washington". State Washington, Dept. Fish., Biol. Bull., 49-A, Seattle, 1949.

Bonham, K., Sanford, F. B., Clegg, W. & Bucher, G. C. "Biological and vitamin A studies of dogfish, *Squalus suckleyi*, landed in the State of Washington". State Washington, Dept. Fish., Biol. Bull., 49-A, Seattle, 1949.

Desbrosses, P. "Note préliminaire sur la Dorade Grise de la Manche *Spondyliosoma cantharus* (Gmel.)". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 139—40, Copenhague, 1950.

Fairbridge, W. S. "The New South Wales tiger flathead, *Neoplatycephalus macrodon* (Ogilby). I. Biology and age determination". Austral. Journ. Mar. Freshw. Res., **2**, 2, pp. 117—78, Melbourne, 1951.

Fairbridge, W. S. "The New South Wales tiger flathead, *Neoplatycephalus macrodon* (Ogilby). II. The age composition of the commercial catch, overfishing of the stocks, and suggested conservation". ibid., **3**, 1, pp. 1—31, Melbourne, 1952.

Faure, J. & Letaconnoux, R. "Rouget-barbet (*Mullus barbatus surmuletus*). Mensurations". Cons. Internat. Explor. Mer, Ann. Biol., **6**, pp. 79—80, Copenhague, 1950.
Halås, M. "Forsøksfiske etter håkjerring i fjordene på vestlandet". Årsber. vedk. Norges Fisk., 1949, 7, pp. 137—42, Bergen, 1950.
Meyer, A. "Der Goldlachs (*Argentina silus*), ein wenig bekannter Speisefisch". Fischereiwelt, **3**, 6, pp. 89—90, Bremerhaven u. Hamburg-Altona, 1951.
Perlmutter, A. & Clarke, G. M. "Age and growth of immature rosefish (*Sebastes marinus*) in the Gulf of Maine and off western Nova Scotia". U. S. Dept. Int., Fish Wildlife Serv., Fish. Bull. 45, Washington, 1945.

8) o Whales and Seals.

Bonham, K. "Duration of life and behaviour of Alaska fur seals in captivity". Journ. Mammal., **24**, 4, p. 504, Seattle, 1943.
Day, A. M. "Old man of the Pribilofs". Sci. Monthly, **68**, 5, pp. 329—37, New York, 1949.
Heldt, H. "Cétacés. Incursions de Baleinoptères sur les côtes tunisiennes". Cons. Internat. Explor. Mer, Ann. Biol., **6**, p. 80, Copenhague, 1950.
Jorpes, J. E. "The insulin content of whale pancreas". Hvalrådets Skr., 35, Oslo, 1950.
Khmelinin, A. "Fur seals in the Okhotsk Sea". Priroda, 8, p. 72, Leningrad, 1950. (In Russian).
Mackintosh, N. A. "Observations on whales from ships". Mar. Observer, **22**, 156, pp. 87—90, H. M. S. O., London, 1952.
Marsh, D. B. "Whales in the Arctic". Canadian Geogr. Journ., **41**, 1, pp. 34—40, Montreal, 1950.
Palm, W. H. G. "Walvisschen en walvischvaart". L. J. Veen's Uitgeversmij N. V., Amsterdam, 1949.
Pedersen, T. "Studies in whale oils on the content of saturated fatty acids in whale oils". Hvalrådets Skr., 34, Oslo, 1950.
Stephenson, W. "The lesser rorqual in British waters". Rep. Dove Mar. Lab. Cullercoats, 3. Ser., 12, pp. 7—48, Newcastle-upon-Tyne, 1951.
Vladykov, V. D. "Nourriture du Marsouin Blanc ou Béluga (*Delphinapterus leucas*) du fleuve Saint-Laurent". Québec Contrib. Dept. Pêch., 17, Québec, 1946.

9) Freshwater Fisheries and Fishery Investigations.

9) a Salmonidae.

Bonham, K. & Seymour, A. H. "Hybrid of chinook and silver salmon from Puget Sound". Copeia, 1, p. 69, New York, 1949.
Bonham, K. "Some tests with experimental groups of fingerling rainbow trout, *Salmo gairdnerii*, on uniformity and rate of growth, diet, and photographic size-recording". Trans. Amer. Fish. Soc., **79**, pp. 94—104, New York, 1950.
Burrows, R. E. "An evaluation of methods of egg enumeration". Prog. Fish-Culturist, **13**, 2, pp. 79—85, Washington, 1951.
Burrows, R. E., Robinson, L. A. & Palmer, D. D. "Tests of hatchery foods for bluejack salmon 1944—48". U. S. Dept. Int., Fish Wildlife Serv., Spec. Sci. Rep. Fish., 59, Washington, 1951.
Davis, H. S. "Care and diseases of trout". U. S. Dept. Int., Fish Wildlife Serv., Res. Rep. 12, Washington, 1947.
Erkkila, L. F., Moffett, J. W., Cope, O. B. & others. "Sacramento — San Joaquin Delta fishery resources: effects of tracy pumping plant and Delta Cross Channel". U. S. Dept. Int., Fish Wildlife Serv., Spec. Sci. Rep. Fish., 56, Washington, 1950.
Foskett, D. R. "Young salmon in Nanaimo area". Prog. Rep. Pacific Coast Stat., 86, pp. 18—9, Vancouver, B. C., 1951.
Goodman, J. R. "Toxicity of zinc for rainbow trout (*Salmo gairdnerii*)". Calif. Fish Game, **37**, 2, pp. 191—4, San Francisco, 1951.
Hayes, F. R., Wilmot, I. R. & Livingstone, D. A. "The oxygen consumption of the salmon egg in relation to development and activity". Journ. Exper. Zool., **116**, 3, pp. 377—95, Philadelphia, 1951.
Hoar, W. S. "The chum and pink salmon fisheries of British Columbia 1917—1947". Bull. Fish. Res. Board Canada, 90, Toronto, 1951.
Palmer, D. D., Johnson, H. E., Robinson, L. A. & Burrows, R. E. "The effect of retardation of the initial feeding on the growth and survival of salmon fingerlings". Prog. Fish-Culturist, **13**, 2, pp. 55—62, Washington, 1951.

Robinson, L. A., Palmer, D. D. & Burrows, R. E. "Tests of hatchery foods for bluejack salmon 1949". U. S. Dept. Int., Fish Wildlife Serv., Spec. Sci. Rep. Fish., 60, Washington, 1951.

Shuman, R. F. "On the effectiveness of spermatozoa of the pink salmon (*Oncorhynchus gorbuscha*) at varying distances from point of dispersal". U. S. Dept. Int., Fish Wildlife Serv., Fish. Bull. 50, Washington, 1950.

Silliman, R. P. "Fluctuations in abundance of Columbia River chinook salmon (*Oncorhynchus tschawytscha*) 1935—45". U. S. Dept. Int., Fish Wildlife Serv., Fish Bull. 51, Washington, 1950.

Went, A. E. J. "Movements of salmon along the coasts of Northern Ireland". Nature, **167**, 4259, pp. 981—2, London, 1951.

9) b Eels.

Burnet, A. M. R. "Studies on the ecology of the New Zealand long-finned eel, *Anguilla dieffenbachii* Gray". Austral. Journ. Mar. Freshw. Res., **3**, 1, pp. 32—63, Melbourne, 1952.

Halås, M. "Fangstforsøk etter nedgangsål høsten 1948". Årsber. vedk. Norges Fisk., 1949, 7, pp. 143—9, Bergen, 1950.

Rasmussen, C. J. "Two Danish finds of female eel (*Anguilla anguilla*) in spawning or partial spawning dress". Rep. Dan. Biol. Stat., 53, pp. 36—9, Copenhagen, 1951.

9) c Other Commercial Species.

Hourston, A. S. "The food and growth of the maskinonge (*Esox masquinongy* Mitchill) in Canadian waters". Journ. Fish. Res. Board Canada, **8**, 5, pp. 347—68, Toronto, 1952.

Smith, M. W. "The lake whitefish in Kerr Lake, New Brunswick". Journ. Fish. Res. Board Canada, **8**, 5, pp. 340—6, Toronto, 1952.

9) d Effects of Pollution.

Davis, C. C. "Studies of the effects of industrial pollution in the Lower Patapsco River area". Chesapeake Biol. Lab., Publ. 72, Solomons Isl., Maryland, 1948.

9) e Ecology.

Bonham, K. & Palumbo, R. F. "Effects of X-rays on snails, crustacea and algae". Growth, **15**, pp. 155—88, Seattle, 1951.

Greze, V. N. "Bottom plankton, its role in the nutrition of fish, and methods of valuation". Zool. Zhurn., **30**, 1, pp. 44—50, Moscow, 1951. (In Russian).

Jolly, V. H. "A preliminary study of the limnology of Lake Hayes". Austral. Journ. Mar. Freshw. Res., **3**, 1, pp. 74—91, Melbourne, 1952.

Macan, T. T. & Worthington, E. B. "Life in lakes and rivers". Collins, London, 1951.

10) Shellfisheries.

10) a Molluscs.

Beaven, G. F. "Effect of Susquehanna River stream flow on Chesapeake Bay salinities and history of past oyster mortalities on Upper Bay bars". Chesapeake Biol. Lab., Contrib. 68, Solomons Isl., Maryland, 1946.

Cahn, A. R. "Pearl culture in Japan". U. S. Dept. Int., Fish Wildlife Serv., Fish. Leaflet 357, Washington, 1949.

Cahn, A. R. "Oyster culture in Japan". U. S. Dept. Int., Fish Wildlife Serv., Fish. Leaflet 383, Washington, 1950.

Carp, B. "Fishery resources of Turkey". U. S. Dept. Int., Fish Wildlife Serv., Fish. Leaflet 390, Washington, 1951.

Coe, W. R. & Fitch, J. E. "Population studies, local growth rates and reproduction of the Pismo clam (*Tivela stultorum*)". Journ. Mar. Res., **9**, 3, pp. 188—210, New Haven, Conn., 1950.

Dannevig, A. "Lobster and oyster in Norway". Cons. Internat. Explor. Mer., Rapp. et Proc.-Verb., **128**, 2, pp. 92—6, Copenhague, 1951.

Galtsoff, P. S. "Reaction of oysters to chlorination". U. S. Dept. Int., Fish Wildlife Serv., Res. Rep. 11, Washington, 1946.

Galtsoff, P. S., Chipman, W. A., Engle, J. B. & Calderwood, H. N. "Ecological and physiological studies of the effect of sulfate pulp mill wastes on oyster in the York River, Virginia". U. S. Dept. Int., Fish Wildlife Serv., Fish. Bull. 43, Washington, 1947.

Grijns, A. "Bacteriological control of Zealand oysters and mussels". Cons. Internat. Explor. Mer, Rapp. et Proc.-Verb., **128**, 2, pp. 48—9, Copenhague, 1951.

Halewyck, R. & Leloup, E. "La situation de l'ostréiculture dans le Bassin de Chasse d'Ostende de 1939 à 1948". Cons. Internat. Explor. Mer, Rapp. et Proc.-Verb., **128**, 2, p. 19, Copenhague, 1951.

Havinga, B. "Shellfish in the Netherlands". Cons. Internat. Explor. Mer, Rapp. et Proc.-Verb., **128**, 2, pp. 64—8, Copenhague, 1951.

Iwata, K. S. "Spawning of *Mytilus edulis* 5. A method to obtain mature eggs from mantle piece". Bull. Japan. Soc. Sci. Fish., **17**, 1, pp. 15—8, Tokyo, 1951.

Iwata, K. S. "Spawning of *Mytilus edulis* 7. Acid-inhibition of spawning by KCl". 8. Comparison of inducing abilities of spawning among salts of alkali metals and of alkali earth metals. 9. Mechanism of spawning by temperature rise". ibid., **17**, 3, pp. 9—16, Tokyo, 1951.

Jones, S. "Observations on the bionomics and fishery of the brown mussel (*Mytilus* sp.) of the Cape Region of Peninsular India". Journ. Bombay Natur. Hist. Soc., **49**, 3, pp. 519—28, Bombay, 1950.

Knight-Jones, E. W. "Aspects of the setting behaviour of larvae of *Ostrea edulis* on Essex oyster beds". Cons. Internat. Explor. Mer, Rapp. et Proc.-Verb., **128**, 2, pp. 30—4, Copenhague, 1951.

Korringa, P. "Difficulties encountered in tank-breeding of oysters (*Ostrea edulis*)". Cons. Internat. Explor. Mer, Rapp. et Proc.-Verb., **128**, 2, pp. 35—8, Copenhague, 1951.

Korringa, P. "Investigations on shell-disease in the oyster, *Ostrea edulis* L." Cons. Internat. Explor. Mer, Rapp. et Proc.-Verb., **128**, 2, pp. 50—4, Copenhague, 1951.

Korringa, P. "*Crepidula fornicata* as an oyster-pest". Cons. Internat. Explor. Mer, Rapp. et Proc.-Verb., **128**, 2, pp. 55—9, Copenhague, 1951.

Lambert, L. "Les huîtres des côtes Françaises, *Ostrea edulis* et *Gryphoea angulata*". Cons. Internat. Explor. Mer, Rapp. et Proc.-Verb., **128**, 2, pp. 20—6, Copenhague, 1951.

Lambert, L. "Le contrôle sanitaire des huîtres, moules et coquillages". Cons. Internat. Explor. Mer, Rapp. et Proc.-Verb., **128**, pp. 43—7, Copenhague, 1951.

Loosanoff, V. L. & Engle, J. B. "Effect of different concentrations of micro-organisms on the feeding of oysters (*O. virginica*)". U. S. Dept. Int., Fish Wildlife Serv., Fish. Bull. 42, Washington, 1947.

Loosanoff, V. L. & Nomejko, C. A. "Spawning and setting of the American oyster, *O. virginica*, in relation to lunar phases". Ecology, **32**, 1, pp. 113—34, Lancaster, Pa., 1951.

Mistakidis, M. N. "Quantitative studies of the bottom fauna of the Essex oyster grounds". Min. Agric. Fish., Fish. Invest., Ser. 2, **17**, 6, H. M. S. O., London, 1951.

Newcombe, C. L. "An analysis of certain dimensional relationships of the Virginia oyster, *Crassostrea virginica* (Gmelin)". American Naturalist, **84**, pp. 203—14, Boston, 1950.

Sherwood, H. P. "The sanitary control of shellfish in England". Cons. Internat. Explor. Mer, Rapp. et Proc.-Verb., **128**, 2, pp. 39—42, Copenhague, 1951.

Sieling, F. W. "Maryland's commercial fishing gears. 2. The oyster gears". Chesapeake Biol. Lab., Educat. Ser., 25, Solomons Isl., Maryland, 1950.

Spärck, R. "Fluctuations in the stock of oyster (*Ostrea edulis*) in the Limfjord in recent time". Cons. Internat. Explor. Mer, Rapp. et Proc.-Verb., **128**, 2, pp. 27—9, Copenhague, 1951.

Stauber, L. A. "The problem of physiological species with special references to oysters and oyster drills". Ecology, **31**, 1, pp. 109—18, Brooklyn, 1950.

Thomson, J. M. "The acclimatization and growth of the Pacific oyster (*Gryphaea gigas*) in Australia". Austral. Journ. Mar. Freshw. Res., **3**, 1, pp. 64—73, Melbourne, 1952.

Vilela, H. "Quelques données sommaires sur l'écologie de *Tapes decussatus* (L.)". Cons. Internat. Explor. Mer, Rapp. et Proc.-Verb., **128**, 2, pp. 60—2, Copenhague, 1951.

Vilela, H. "Invertébrés marins, comestibles, du Portugal". Cons. Perm. Internat. Explor. Mer, Rapp. et Proc.-Verb., **128**, 2, p. 63, Copenhague, 1951.

10) b Crustacea.

Cronin, L. E. "Comparison of methods of tagging the blue crab". Ecology, **30**, 3, pp. 390—4, Brooklyn, 1949.

Dannevig, A. "Lobster and oyster in Norway". Cons. Internat. Explor. Mer, Rapp. et Proc.-Verb., **128**, 2, pp. 92—6, Copenhague, 1951.

Desbrosses, P. "*Cancer pagurus* L. Informations sur l'intensité de la pêche et les migrations de l'espèce près des côtes de France". Cons. Internat. Explor. Mer, Rapp. et Proc.-Verb., **128**, 2, pp. 82—3, Copenhague, 1951.
McMynn, R. G. "The crab fishery off Graham Island, British Columbia, to 1948". Bull. Fish. Res. Board Canada, 91, Toronto, 1951.
Poulsen, E. M. "On the crustaceans of commercial importance in Danish waters". Cons. Internat. Explor. Mer, Rapp. et Proc.-Verb., **128**, 2, pp. 69—78, Copenhague, 1951.
Rasmussen, B. "Some problems in the fishery for deep sea prawns". Cons. Internat. Explor. Mer, Rapp. et Proc.-Verb., **128**, 2, pp. 79—81, Copenhague, 1951.
Thomas, H. J. "Fluctuations in the lobster (*Homarus vulgaris*) population of the Scottish coast". Cons. Internat. Explor. Mer. Rapp. et Proc.-Verb., **128**, 2, pp. 84—91, Copenhague, 1951.

11) Miscellaneous.

11) a General.

Anon. "Effects of underwater explosions on oysters, crabs and fish". Chesapeake Biol. Lab., Publ. 70, Solomons Isl., Maryland, 1948.
Breitfuss, L. L. "Erforschung der Polargebiete 1932—47". Geogr. Jahrb., **60**, Gotha, 1950.
Cutting, C. L. "Economic aspects of the utilization of fish". Biochem. Fish, Biochem. Soc. Symposia, 6, pp. 86—104, Cambridge, 1951.
Dunn, A. & Coker, C. M. "Notes on marking live fish with biological stains". Copeia, 1, pp. 28—31, Ann Arbor, Mich., 1951.
le Grand, Y. "Leçon d'ouverture du cours d'océanographie physique". Bull. Inst. Océanogr., 982, Monaco, 1951.
Hile, R. "Standardization of methods of expressing lengths and weights of fish". Trans. Amer. Fish. Soc., **75** (1945), pp. 157—64, New York, 1948.
Hile, R. "A nomograph for the computation of the growth of fish from scale measurements". Trans. Amer. Fish. Soc., **78** (1948), pp. 156—62, New York, 1950.
Kiparsky, V. "L'histoire du morse". Ann. Acad. Sci. Fennica, Ser. B, **73**, 3, Helsinki, 1952.
Sanford, F. B. & Bonham, K. "Absence of vitamin A in liver oil of the brown shark". Science, **111**, 2887, p. 475, New York, 1950.
Scattergood, L. W. (Compiler). "English translations of fishery literature". U. S. Dept. Int., Fish Wildlife Serv., Spec. Sci. Rep. Fish., 35, Washington, 1951.
Williams, R. T. (Edit.). "The biochemistry of fish". Biochem. Soc. Symposia, 6, Cambridge, 1951.
Wilson, R. C. "The M. V. 'Yellowfin', an addition to California's marine fisheries investigations". Calif. Fish Game, **37**, 2, pp. 133—9, San Francisco, 1951.

11) b Mathematical and Statistical Methods.

Barnes, H. & Marshall, S. M. "On the variability of replicate plankton samples and some applications of 'contagious' series to the statistical distribution of catches over restricted periods". Journ. Mar. Biol. Assoc. U. K., **30**, 2, pp. 233—63, Cambridge, 1951.

Index to Volume XVIII.

Articles.

Aabye Jensen, E. and **E. Steemann Nielsen.** A Water-Sampler for Biological Purposes 296
Barnes, H. The Use of Transformations in Marine Biological Statistics 61
Bather, J. M. and **J. P. Riley.** The Precise and Routine Potentiometric Determination of the Chlorinity of Sea Water 277
Burkenroad, Martin D. Theory and Practice of Marine Fishery Management 300
Cadenat, J. Contribution à l'Etude du Merlu de l'Atlantique. D. Note au Sujet des Merlus de la Région de Dakar 230
Coupé, René. Note préliminaire sur les Sparidés des Côtes du Maroc .. 37
Coupé, René. Note sur *Pagellus acarne* (Risso) 38
Cushing, D. H. Echo-Surveys of Fish 45
Deelder, C. L. On the Migration of the Elver (*Anguilla vulgaris* Turt.) at Sea 187
Dollfus, Robert Ph. Parasites du *Germo alalunga* (J. F. Gmelin 1888) .. 42
Dunlop, H. A. and **F. H. Bell.** New Problems in Regulation of Pacific Halibut Stocks 167
Einarsson, Hermann. Analysis of the Icelandic Herring during the Year 1950 172
le Gall, Jean. Contribution à l'Etude du Merlu de l'Atlantique
Préface. Le "Problème du Merlu" 219
A. Les Espèces et Variétés du Genre *Merluccius* Raffinesque 221
F. Etude Biométrique du Merlu 236
Heldt, H. Contribution à l'Etude du Merlu de l'Atlantique. E. Note Préliminaire sur le Merlu des Mers Tunisiennes. 234
Letaconnoux, R. Contribution à l'Etude du Merlu de l'Atlantique. B. Note sur le Merlu de la Côte d'Afrique 223
Maurin, Claude. Contribution à l'Etude du Merlu de l'Atlantique. C. Les Merlus des Côtes Atlantiques du Maroc 224
Roberts, C. H. An Automatic Collector for Water and Plankton Samples 107
Schell, I. I. On the Role of the Ice off Iceland in the Decadal Air Temperatures of Iceland, and some other Areas 11
Steemann Nielsen, E. The Use of Radio-active Carbon (C^{14}) for Measuring Organic Production in the Sea 117
Sverdrup, H. U. On Conditions for the Vernal Blooming of Phytoplankton 287
Thomas, H. J. The Efficiency of Fishing Methods Employed in the Capture of Lobsters and Crabs 333
Thompson, W. F. Condition of Stocks of Halibut in the Pacific 141
Went, Arthur E. J. Salmon of the River Shannon (1948—1951) 326
Westenberg, J. Acoustical Aspects of some Indonesian Fisheries 311

Reviews.

Alm, Gunnar. The Sea-Trout Population in the Åva Stream. (P. R. C. Macfarlane) 254
Bailey, N. T. J. On estimating the size of mobile populations from recapture data. (J. A. Gulland) 365
Blegvad, H. Fluctuations in the Amounts of Food Animals of the Bottom of the Limfjord in 1928—1950. (A. D. McIntyre) 363
Bruun, A. F. Scientific Results of the Danish Expedition to the Coasts of Tropical West-Africa 1945—46. (H. Blegvad †) 74
Clowes, A. J. An Introduction to the Hydrology of South African Waters. (G. Dietrich) 245
Dannevig, G. Sprats from Norwegian Waters. An Analysis of Vertebrae Counts. (I. Richardson) 80
DeLury, D. B. On the planning of experiments for the estimation of fish populations. (J. A. Gulland) 365
Ehnholm, G. Studier över strömmingen i Östra Kvarken. (Chr. Hessle) 367
Forster, G. R. The biology of the common prawn *Leander serratus* Pennant. (P. Desbrosses) 371
Forster, G. R. Notes on *Leander squilla* L. (P. Desbrosses) 372
Fuglister, F. C. Annual Variations in Current Speeds in the Gulf Stream System. (E. W. Barlow) 360
Hodgson, W. C. Echo-Sounding and the Pelagic Fisheries. (B. B. Parrish). 251
Holthuis, L. B. The Caridean Crustacea of Tropical West Africa. (I. Gordon) 361
Jones, J. W. Salmon Studies 1950. (A. E. J. Went) 368
Jonsgård, Åge. Studies on the Little Piked Whale or Minke Whale (*Balaenoptera acuto-rostrata* Lacépède). Report on Norwegian investigations carried out in the years 1943—1950. (N. A. Mackintosh) 80
Ketchum, B. H., A. C. Redfield, and J. C. Ayres. The Oceanography of the New York Bight. (David Vaux) 246
Knudsen, Jørgen. Contributions to the Biology of the Whiting (*Gadus merlangus* L.) in the Danish Waters. (B. B. Rae) 366
Leslie, P. H. and D. Chitty. The estimation of population parameters from data obtained by means of the capture-recapture method. I. The maximum likelihood equations for estimating the death rate. (J. A. Gulland) 365
Loosanoff, V. L., W. S. Miller, and P. B. Smith. Growth and setting of larvae of *Venus mercenaria* in relation to temperature. (H. A. Cole) 249
Lübbert, Hans. Die grossen Seefischereien der Erde, ihre Fanggründe und ihre Fangprodukte. (Niels Rosén) 77
Mistakidis, M. N. Quantitative studies of the bottom fauna of Essex oyster grounds. (P. Korringa) 369
Moran, P. A. P. A mathematical theory of animal trapping. (J. A. Gulland) 365
Mortensen, Th. Report on the Echinoidea collected by the "Atlantide" Expedition. (I. Gordon) 364
Neumann, G. Gibt es eine "Kritische Windgeschwindigkeit" für die Grenzfläche Wasser-Luft? (H. Charnock) 75
Poulsen, E. M. Changes in the Frequency of Larger Bottom Invertebrates in the Limfjord in 1927—1950. (A. D. McIntyre) 363
Rees, C. B. The Identification and Classification of Lamellibranch Larvae. (C. Barker Jørgensen) 369
Reid, D. M. Report on the Amphipoda (Gammaridea and Caprellidae) of the Coast of Tropical West Africa. (I. Gordon) 362
Riley, G. A. Parameters of Turbulence in the Sea. (K. F. Bowden) 359
Rochford, D. J. Studies in Australian Estuarine Hydrology. I. Introductory and Comparative Features. (John P. Tully) 247

Simpson, A. C. The Fecundity of the Plaice. (G. Svärdson) 79
Smith, Gilbert M. (edited by). Manual of Phycology. An Introduction to the Algae and their Biology. (Sheila Lodge) 250
Went, A. E. J. Movements of Salmon around Ireland. 1. From Achill, Co. Mayo (1948—50). (P. R. C. Macfarlane) 253
Wiborg, K. F. The Whirling Vessel. An apparatus for the fractioning of plankton samples. (D. H. Cushing) 76

Notices and Correspondence.

Obituary Notices:—
Blegvad, Harald (1886—1951) by E. M. Poulsen 3
Dahl, Knut (1871—1951) by Sven Sømme 101
Jespersen, Poul (1891—1951) by F. S. Russell 104
Lissner, Helmuth (1897—1951) by O. H. Oren 7

Letters to the Editor:—
A. C. Simpson and **Michael Graham** (Winds and Brood Strengths) .. 73
Rosemary H. Lowe (Elver Catches in the River Bann — Vol. XVII, 3) 241
J. A. Gulland (Correlations on Fisheries Hydrography) 351
J. N. Carruthers, A. L. Lawford and **V. F. C. Veley** (Winds and Fish Fortunes) 354

Notes and Errata:—
Offprints from the Council's Publications 72
Errata to I. I. Schell, pp. 27 and 28 358

Current Bibliography.

Current Bibliography prepared by the Editor with the Assistance of Mr. A. C. Simpson ..... 82, 256 and 374

Recent Publications of the International Council:

RAPPORTS ET PROCÈS-VERBAUX.

Vol. No. 131: Contributions to Special Scientific Meeting 1951. Fisheries Hydrography. Juin 1952. Kr. 22.00.

Vol. No. 132: Rapport Jubilaire (1927—1952). Septembre 1952. Kr. 14.00.

Vol. No. 133: Rapport. Trygve Braarud, Karen R. Gaarder & Jul. Grøntved: The Nano-Plankton of the North Sea and adjacent Waters, with Special Reference to the International Survey, May 1948. In preparation.

Vol. No. 134: Procès-Verbaux (Sept./Oct.—1952). Rapport Administratif (1951). In preparation.

ANNALES BIOLOGIQUES.

Vol. No. VII: 1950. Décembre 1951. Kr. 25.00.
Vol. No. VIII: 1951. Décembre 1952. Kr. 30.00.

BULLETIN HYDROGRAPHIQUE pour l'année 1948. Janvier 1952. Kr. 25.00.
pour l'année 1949. In preparation.

BULLETIN STATISTIQUE pour l'année 1949. Septembre 1952. Kr. 8.00.
pour l'année 1950. In preparation.

FICHES D'IDENTIFICATION DU ZOOPLANCTON.

Nos. 1—17. Mai 1949. Kr. 10.00.
Nos. 18—29. Novembre 1950. Kr. 10.00.
Nos. 30—40. Septembre 1951. Kr. 12.00.
Nos. 41—49. Août 1952. Kr. 12.00.

HERRING ATLAS. — Fisheries of the North-Eastern Atlantic (Fishing Ground, Landing Ports and Quality). Octobre 1950. Kr. 32.00.

Table of Contents.

		Page
1.	**J. M. Bather and J. P. Riley.** The Precise and Routine Potentiometric Determination of the Chlorinity of Sea Water	277
2.	**H. U. Sverdrup.** On Conditions for the Vernal Blooming of Phytoplankton	287
3.	**E. Aabye Jensen and E. Steemann Nielsen.** A Water-Sampler for Biological Purposes	296
4.	**Martin D. Burkenroad.** Theory and Practice of Marine Fishery Management	300
5.	**J. Westenberg.** Acoustical Aspects of some Indonesian Fisheries	311
6.	**Arthur E. J. Went.** Salmon of the River Shannon (1948-1951)	326
7.	**H. J. Thomas.** The Efficiency of Fishing Methods Employed in the Capture of Lobsters and Crabs	333
8.	Letters to the Editor; **J. A. Gulland: J. N. Carruthers, A. L. Lawford,** and V. F. C. Veley (Correlations on Fisheries Hydrography)	351
9.	Errata (to I. I. Schell, pp. 27 and 28)	358
10.	Reviews	359
11.	Current Bibliography prepared by the Editor with the Assistance of Mr. A. C. Simpson	374
12.	Index to Volume XVIII	391

A/S L. IHRICH . COPENHAGEN